13

ROYAL SOCIETY.

REPORTS TO THE MALARIA COMMITTEE,

1899–1900.

CONTENTS.

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ERRATA.

Page 24, line 22. *Omit* "Report I."
,, 26 ,, 29. *For* "plasterer" *read* "planter."
,, ,, lines 41 and 43. *For* "Inpimbe" *read* "Mpimbe."
,, 27, line 2. *Omit* "Case I."
,, 28 ,, 2. *For* "Case II" *read* "Case III"; *omit* "*vide* also Chart X."
,, 30, lines 28 and 37. *For* "Bright's" *read* "Weigert's."
,, 31 ,, 3 and 37. *For* "K_4TeCy_{76}" *read* "K_4FeCy_6."
,, 32, line 13. *For* "narrow" *read* "marrow."
,, 33 ,, 2. *For* "Case III" *read* "Case IV"; *omit* "*vide* also Chart VII."
,, 36 ,, 2. *For* "Case IV" *read* "Case V"; *omit* "*vide* also Chart VIII."
,, 38 ,, 12. *For* "Chart IV" read "Chart VIII."
,, ,, ,, 18, columns 4 and 5. *For* "H" *read* "No."
,, ,, ,, 19 ,, ,, ,, ,,
,, ,, ,, 21 ,, ,, ,, ,,
,, ,, ,, 22 ,, ,, ,, ,,
,, 40 ,, 6. *For* "Case V" *read* "Case II"; *omit* "*vide* also Chart IX."
,, 41 ,, 42. *For* "Chart V" *read* "Chart VI."
,, 62 ,, 41. *For* "Case I" *read* "Case II."
,, 63 ,, 25. *For* "Case II" *read* "Case III."
,, 66 ,, 10. *For* "Case I" *read* "Case II"; *omit* "of our previous report."
,, 69 ,, 13. *For* "Case I" *read* "Case II."
,, ,, ,, 15. *For* "Case III" *read* "Case IV."
,, ,, ,, 22. *For* "Case II" *read* "Case III."

REPORTS TO THE MALARIA COMMITTEE OF THE ROYAL SOCIETY.

"On Transmission of Proteosoma to Birds by the Mosquito: a Report to the Malaria Committee of the Royal Society." By Dr C. W. DANIELS. Communicated by Dr. M. FOSTER, Sec.R.S., by direction of the Malaria Committee. Received February 13,—Read March 16, 1899.

I have the honour to report the results of my observations since my arrival here (Calcutta) on December 21, 1898.

2. Major Ronald Ross, I.M.S., after demonstrating and explaining to me his method of dissecting the mosquito, showed me in prepared specimens the pigmented bodies met with in the stomach walls of mosquitoes fed on birds infected with Proteosoma, and also the changes which these bodies undergo day by day. Finally he demonstrated to me the "germinal threads" in cysts in the stomach wall, in the fluids of the body, and in the cells of the veneno-salivary glands.

3. On my arrival there were in the laboratory, in test-tubes, several series of mosquitoes which had fed on birds infected with Proteosoma on the nights of November 30, December 10, December 12, December 15, and December 20.

Of each of these series Major Ross dissected specimens, and demonstrated in them the same bodies that he had already shown me in prepared specimens. He pointed out that in the older mosquitoes it was possible to predict from an examination of the fluid obtained on cutting the thorax the nature of the contents both of the "coccidia" (the term employed by Ross)* in the stomach, and of the cells of the veneno-salivary glands.

These points I readily observed.

4. Of the mosquitoes referred to I day by day examined those which died, and others which I killed. In these I was able to repeat the observations and, in insects belonging to the earlier series, to trace

* See note by the Malaria Committee appended to this Report.

these did I find either "coccidia" in the stomach wall, germinal threads in the body fluids, or germinal threads in the cells in the salivary glands; nor did I find "black spores" (Ross).

5. Major Ross informed me that his published results were based on observations made in the hot season, when the temperature was 80° F., or over; and that now, as it was the cool season, I should find the changes progress more slowly, although the sequence of events was the same. My observations on the mosquitoes fed on December 20 and December 15 showed that this was the case. Major Ross also informed me that, with the lowered temperature, mosquitoes fed less readily, and that more difficulty was experienced in rearing them to a spore-bearing age.

These difficulties the use of the incubator was only partially successful in overcoming.

6. On the evening of January 1, following exactly in Major Ross's lines, I commenced a repetition of his main experiment:—

A large number of grey mosquitoes, reared from larvæ, were released in two mosquito nets.

In net No. 1 four birds were placed. On December 31 I had already found Proteosomata in large numbers in three of these birds, and in the fourth in moderate numbers.

In net No. 2 two birds, in whose blood no Proteosomata had been found, were placed. These two birds died two and three weeks later; on dissection no black pigment was found in their organs. Repeated examinations of their blood had failed to discover Proteosomata.

On January 2 none of the mosquitoes had fed, and on January 3 only two in net No. 1 and eight in net No. 2. On January 4, which was a warm night with a minimum temperature of 59·2° F., sixty-three mosquitoes were found in the morning gorged with blood in net No. 1, and were caught in separate test-tubes, which were then plugged with wool and placed in the incubator. Of the control series in net No. 2, where the non-infected birds had been placed, eighteen were caught and treated in the same way.

On the following two evenings, with minimum temperatures of 60·7° and 63·2°, sixty-three and forty-six mosquitoes were fed on the infected birds, net No. 1, and were kept for the preparation of specimens; and twelve mosquitoes were fed on the non-infected birds, net No. 2, bringing the number of the control series up to thirty-eight. At a later date eighteen mosquitoes were fed on a blue jay with numerous Halteridia.

On the third day the sixty-three mosquitoes, from net No. 1 (with

exception of those previously killed for examination or which had died), were released inside a clean net free from other mosquitoes. Birds free from Proteosoma were also placed in this net.*

In the morning all mosquitoes found inside were collected. Most of them had fed well. The minimum temperature during the night had been 63·2° F.

The mosquitoes were not fed on the following night as they were full of blood, which most of them voided during the night. Many died next day.

The remainder were given the opportunity of re-feeding every night after this; but as a spell of cold weather set in with minimum temperature of 44—49° F. (only on one night did it exceed 50° F.) few fed well or at all, and there was a consequent continued heavy mortality. Only one insect, which subsequently escaped in the night, being alive on the 10th day.

This method of feeding was very unsatisfactory in exceptionally cold weather. During the day the mosquitoes being kept warm in the incubator rapidly digested their food, whilst at night the cold rendered them torpid and they did not feed.

The control mosquitoes, of net No, 2, were treated in exactly the same manner, being fed on birds free from Proteosoma. The last died on the 13th day.

7. The results of the two series are as follows:—

Of sixty-three mosquitoes fed on proteosomal birds, forty-nine were examined, three were reserved for sections, one was too much decomposed for satisfactory examination; ten were not accounted for, having been lost in the nets.

Of the forty-nine examined two were killed on the first day—that is, under twenty-four hours, and possibly under twelve hours, after they had fed; no coccidia were found in these. Two more were examined the following morning—that is, under thirty-six and possibly under twenty-four hours after they had fed; no coccidia were found in these. In two examined about 4 p.m. of the same day—that is, under forty-six and possibly not more than thirty-four hours after they had fed on the infected birds, minute pigmented coccidia were found.

The remainder were examined on the following days. The largest

* This is the method Ross employs to re-feed mosquitoes. If infected birds are employed to re-feed the insects, a younger generation of coccidia is produced; I therefore used sterile birds for this purpose.

The method works fairly well in warm weather, but there is always some loss, as the full number is never collected again in the morning. As the process is repeated over and over again, this loss becomes serious, the more so the longer the period required for maturation of the coccidia. Moreover, in a frequently repeated process of this kind there is always the possibility of an outside mosquito getting inside the net, and to that extent vitiating the experiment.

In all these mosquitoes, with one exception, coccidia were found—usually in numbers; in one there was only one coccidium.

The exception occurred on the ninth day; but as by that time the insects had been re-fed several times, the mosquito in question may have been an outside one which had effected an entrance.

Of forty-five mosquitoes fed on the infected birds and examined, more than thirty-four hours after, forty-four contained coccidia.

This I may say is a more successful result than in the other series I have seen.

The other two series of mosquitoes were used by all of us for the preparation of specimens, and no record was kept of the number of non-infected insects. Judging from my own examination, only about three-quarters of them developed coccidia. Their treatment had been somewhat different, as for several days half of them were not incubated.

Of the controls fed on birds free from Proteosoma, thirty-eight in number, and treated in the same manner, twenty-nine were examined and nine are unaccounted for—lost in the nets. None of the twenty-nine were examined on the first day, but one was on the afternoon of the second day. The largest number, seven and five, were examined on what would correspond to the fourth and seventh days, four were examined on the fifth and four on the sixth days.* In none of these twenty-nine were coccidia found.

Of the eighteen fed on the blue jay with Halteridia, twelve were examined from two to six days after feeding; none contained coccidia.

8. The coccidia (pigmented bodies) found on the second day measured 6—7 μ, some of them a little more. They were oval bodies containing scattered granules of black pigment, and had a sharp, clear outline.

I incised the stomach of infected mosquitoes and by repeated washing and compression with a cover glass was able not only to wash out the contents, but even to express the loosely attached epithelium, so as to leave the stomach a transparent clear bag. The majority of coccidia remained fixed to the outer wall, though in one of the mosquitoes I observed a few coccidia escape with the epithelium. On subsequent attempts to detach the coccidia by this process I failed to do so, though some coccidia would be ruptured.

The next morning the smallest coccidia measured 10 μ; some were

* It will be observed that these control mosquitoes were not, as the other series, collected on one, but on three nights. A very slight difference in breeze and light seems to affect the numbers that feed; any extra restlessness on the part of the birds has the same result.

$12\,\mu$. On the sixth day they were met with up to $30\,\mu$; by this time the pigment had absolutely as well as relatively diminished.

In another three days some of them reached $60\,\mu$; and in the last of the series examined (tenth day), there were coccidia measuring $70\,\mu$.

The coccidia could now be seen to project from the outer wall of the stomach; very few contained pigment, and that only in small amount.

Some of the coccidia were clear, and others had a granular appearance; but in none were either black spores or germinal threads to be seen.

9. For the observation of the further development of the coccidium the early deaths of the mosquitoes, owing to the inclemency of the weather, rendered this series useless.

One of the insects infected on the night of January 5, and another infected on January 7, did reach this more advanced stage; and in the last of those fed on January 5, and which died on January 22, ruptured cysts, as well as numerous cysts containing mature germinal threads were found by me in the stomach wall; these threads were also found in the body fluids and in cells in the salivary glands. In one of the mosquitoes infected on January 5, which died on January 19, the coccidia had an appearance of striation.

In consequence of the effects of the unfavourable climatic conditions on the experimental insects, my observations on the development of the proteosomal coccidium were mainly made on mosquitoes infected November 30 and subsequent dates before my arrival, and on some infected on December 22.

On adding salt solution (15 grs. to the ounce) to an ordinary slide containing an infected mosquito stomach, and pressing on the cover glass, a projecting coccidium was ruptured; the contents poured out into the fluid, leaving the cyst wall still attached to the stomach.

The contents were seen to consist of a mass of shrivelled threads. This appearance I frequently observed in the other series of infected insects already mentioned.

These threads, Ross's germinal threads, are sickle-shaped bodies, about 14 or $15\,\mu$ in length. They stain with logwood or methyl blue, but not strongly. On adding water or Farrant's solution they lose their shrivelled appearance, and become more rounded. Nearer one end than the other is an unstained portion (? nucleus). They show no signs of movement; but as they are invisible in water, and only become visible when shrivelled by the salt or stained, it may be doubted if they have been seen alive.

If the thorax of the mosquito at a somewhat more advanced stage in the development of the proteosomal coccidium is incised, similar threads will be found in the fluid exuded, if salt solution is added. In this case ruptured cysts can be found in the stomach wall.

The relation of the infection to the veneno-salivary gland involves a difficulty not met with in any other part of the examination.

The dissection of the stomach is easy; that of the salivary gland in its entirety is not, and for some reason appears to be more difficult in the old infected mosquitoes. Any rough manipulation results in the detachment of the cells, and little more than the duct is left. In most cases, however, even in old infected mosquitoes, one entire gland, or portions of both, can be exposed in fair condition.

In every case where this was done, and in which germinal threads were found in the body-fluids, the germinal threads were also found in some of the cells of the salivary gland. I failed to find similar threads in the large number of salivary glands obtained from uninfected mosquitoes bred from larvæ, or caught about the laboratory, or from mosquitoes at the earlier stages of proteosomal infection.

The affected cells, as they have a granular appearance, can be distinguished with a low power; the unaffected cells are quite clear.

With a high power, if not very numerous, the isolated germinal threads can be clearly distinguished in the cells; they are recognised by their peculiar shape and shrivelled appearance (the examination must be made in salt solution). If numerous, the individual threads can be better made out in the cells of the salivary gland than in the coccidia of the stomach wall; but, as in the case of the latter, pressure on the cover glass will rupture the cell, and the germinal threads are then poured out.

The threads do not fill the cell. There is a faintly granular crescentic portion on the side most remote from the duct which, in many cases at least, is free from threads. The part of the cell in which the threads lie must be nearly fluid, as it permits oscillation of the threads to take place.

The whole of the veneno-salivary gland is never involved. In one dissection made by Ross the cells in both middle lobes and in no other part of the gland contained the threads. In several instances, where one gland has been exposed entire, the middle lobe alone has been involved; but in the majority all that can be stated with certainty is that the cells in one portion of the gland contain threads, and that those in the other portions do not.

On these points I have satisfied myself by repeated examination, though the appearances are by no means difficult to make out.

I have gone at some length into the description of this matter, as, so far, we have found no satisfactory method of making permanent preparations. All the preservatives at our disposal, with the exception to some extent of weak formalin solution, wrinkle up the delicate cells; and I have no confidence in this agent as a means of making permanent specimens.

The following specific observations made by myself on mosquitoes

dissected by Major Ross, Dr. Rivenberg, of the American Mission, who is working with Dr. Ross, and myself may be of interest:—

(*a*) Coccidial cysts full of apparently mature germinal threads; no ruptured cysts; no germinal threads in the body-fluids or salivary glands. Two observations.

(*b*) Cysts full of germinal threads; other ruptured empty cysts; germinal threads in body-fluids; germinal threads in salivary glands. Over twenty observations.

(*c*) Empty cysts in stomach wall; germinal threads in body-fluids of thorax; germinal threads in salivary glands; no cysts still containing germinal threads. Two observations.

(*d*) Empty cysts only in stomach wall; no germinal threads in body cavity; no germinal threads in well exposed salivary glands. One observation; the mosquito had been infected four weeks before death.

These observations fully confirm Ross's statement in every point. They indicate that the threads are formed in the coccidia; and that the germinal threads escape into the body cavity on the rupture of the coccidia, to be again collected in the salivary glands.

I should have liked to extend the series, but the continued cold weather renders it improbable that I shall be able to do so before I leave.

10. The infection of birds free from Proteosoma by the bites of mosquitoes.

On December 20, the day before my arrival, twenty-two birds were examined and found free from Proteosoma. On that night some of these birds were used for feeding the mosquitoes which had been infected on November 30 (?) and on the 24th and subsequent days; the remainder of the birds were used for feeding the mosquitoes first infected on November 30 and December 10, 12, and 15. In other mosquitoes of this series germinal threads were found in the salivary glands; and those which fed, when examined later, gave the results indicated in paragraph 9.

On December 30 Dr. Rivenberg and myself examined these birds; three of them had Proteosoma, two in large numbers.

On January 4 I examined them all except one which died on January 2; in this bird the heart's blood contained no Proteosomata, and the organs were free from pigment.

Five more of them had now Proteosoma; in every instance the parasites were very numerous. On January 6 and 7 I again examined them; three more had Proteosoma, also in large numbers.

On January 9 no more cases had developed; but on January 18 one of the birds had numerous Proteosomata. It was also ascertained that many of these birds which previously had been found to be infected had now recovered, whilst others showed but a few Proteosomata.

Thus twelve out of twenty-two birds (54 per cent.) became infected. This compares unfavourably with Ross's earlier results, as, in his published series, twenty-two out of twenty-eight (79 per cent.) were infected. But it is to be remembered that at the time this result was obtained the germinal threads were found at the end of a week; whilst in December the development was much slower, and took at least twice the time. It is much easier to keep mosquitoes alive during the first week after feeding them than it is to keep them alive for any subsequent period; moreover, in hot weather, such as Ross had worked in, mosquitoes bite more readily.

These results appear less unfavourable, if they are considered in connection with observations on the normal proportion of wild, uncaged birds, infected with Proteosoma at this season. Thus, earlier in the year, Ross, out of 111 wild birds, found Proteosoma in fifteen, or 13·5 per cent.; whilst I found at this season only one out of thirty, or 3·3 per cent., affected with Proteosoma.

It is possible that in the cold season the birds have a greater power of resistance; the validity of this conjecture is rendered more probable by the short duration of the proteosomal attack in my infected birds. Of the twelve, five died within the first week. In three of the survivors, in which the Proteosomata had been very numerous, no parasites could be found ten days after the commencement of the invasion; in one in which they were never numerous none could be found on the fifth day. In the other three very few are now found, though at first they were numerous.

The recovery of these birds and the death of the mosquitoes fed on them diminishes the chances of much future work on this line during the time remaining to me here.

11. Mention has been made of the differentiation of the coccidia (previous to the formation of the germinal threads), according to the appearance of their contents, into clear and granular; the evolution of the latter into the coccidia containing germinal threads can be traced day by day. This differentiation was clearly visible in my series.

In a minority of the coccidia, and in most infected mosquitoes, when the germinal threads are mature, certain black tubular bodies are to be found in cysts with otherwise clear contents. These black tubular bodies were frequently met with in the series of mosquitoes infected in November and December. Most of these mosquitoes contained some coccidia with black tubular spore-like bodies; though in a few insects all the cysts contained germinal threads only. In some cysts the black spores were numerous, and occupied the entire cyst; in other cysts there were only a few. In most instances germinal threads were not found in the black spore-bearing cysts; but there were a few such cysts in which it was doubtful whether germinal

threads were present or not, or whether the appearance arose from overlying threads which had escaped from a neighbouring capsule.

These black spores are very resistant; I have seen some which had been kept in water for months by Ross, and which had undergone no visible change. They withstand irrigation with liquor potassæ.

When the cysts are ruptured the black spores are to be found all over the body of the mosquito, but not included in cells. They do not seem to accumulate in any particular organ.

The most plausible view of the nature of these black spores seems to be that held by Major Ross, viz., that they are "resting spores," and that through them, by another cycle, the Proteosoma can be propagated in conditions unfavourable for direct propagation by mosquito-insertion into a warm-blooded animal.

If this be the case, three courses suggest themselves:—

(*a*) From the black spores may arise bodies capable of non-parasitic life (and possibly of reproduction), which at certain stages of their existence, and in certain conditions, on introduction into a warm-blooded host by inhalation, through drinking water, or even by injection by a mosquito or other blood-sucker in transferring them from the medium in which they live, may resume parasitic habits.

(*b*) That they may be ingested by mosquito larvæ, and in them undergo such development as will result in the formation of germinal threads in the adult mosquito, which, in turn, may be injected into the appropriate bird.

(*c*) That they may, if swallowed or inhaled by an appropriate warm-blooded host, so develop as to reach the circulation and pass into the sporulating phase.

Such experiments as have been made on this subject are inconclusive; and it is obvious that until the nature of these "black spores" is determined we cannot exclude, even for Proteosoma of sparrows, the possibility of any one of the many possible alternative channels of infection. Intervention of the mosquito intermediate host may be only an occasional requirement.

Still less are we justified in concluding that malaria in man can only be acquired through and directly from the mosquito; or in devoting our attention exclusively to that channel.

12. I have made myself familiar with the Proteosoma in sparrows, and the Halteridium in pigeons and crows.

In one specimen of a "blue jay," also, I found a very abundant Halteridium infection; the parasites in this instance had some peculiarities which I hope to work out if we can procure more of these birds. The bird I had died before I had completed my observation; I have preserved the organs as well as specimens of the blood in the heart.

13. In the cardiac blood of this jay there were numerous filariæ. They were sheathless, sharp tailed and fairly active, and had locomotory movement. They were of two sizes; in the shorter the tapering of the tail was much more abrupt than in the longer. Neither showed any extension or contraction.

Adults of one species only, three females and five males, were found in the subcuticular connective tissue, and in that round the trachea.

They were much longer and thicker than *Filariæ clava* (Wedl) or than the filaria described by Mazzini in the pigeon.

The females have the usual double ovary terminating in a vagina which appears tubular near the vulva situated near the caudal end of the body. The mouth is terminal and unarmed; the anus is subterminal.

The male has two spicules of equal length. The thickness of these worms, and the fact that when placed in weak formalin (2 per cent.) the cuticle burst in its entire length, will make them suitable for determining some of the disputed points in the anatomy of the Filaridæ.*

14. The difficulties in connection with human malaria are increased by the present plague scare. The suspicion of the natives about inoculation, makes them averse to any intercourse with European medical men.

By rewards, however, we have been able to get two fair cases of tertian fever, and three cases with crescent plasmodia—two of them with crescents in considerable numbers. On these cases we have fed mosquitoes—the common grey, and two varieties of "dapple wings" (large and small) in most points closely resembling those in which Ross had previously found pigmented cells after feeding on a patient with crescents. So far our results have been negative; but, in view of the peculiar climatic conditions, and of the possibility of the first stage, that of formation of coccidia, being inhibited by the cold, we are not prepared to accept these results as conclusive.

15. With Major Ross, I have examined the organs of some persons (eight) who died of kala azar. This appears to be an infectious disease, indistinguishable at first from malaria. Chronic in character, it continues for months and becomes associated with enlargement of the spleen and liver, and progressive anæmia. The present opinion of most of those who have been deputed to investigate kala azar, as well as of those with longest and most intimate experience of the disease, is strongly in favour of the view that it is malarial in origin.

The melanin or black pigment was absent in the organs of some of

* Judging from the description of the embryos, it is probable that these blood-worms of the Indian blue jay are identical with those found by Manson in Amoy, China, in the magpie (*Pica media*) and the gray mina (*Gracupica nigricollis*), in which case the mature form of one will be found to lie in the pockets of the aortic and pulmonary semi-lunar valves (*vide* 'Journ. of the Queckett Micro. Club,' vol. 6, p. 130, No. 44, August, 1880).

the cases I examined; but in all but one yellow pigment was present in the liver, and in most in the kidneys and spleen also, indicating hæmolysis. The iron reaction with acidified potassium ferrocyanide was obtained in the spleen in three instances and, in one, in the liver also.

So abundant and chronic a hæmolysis in cases of malaria, continued moreover after the parasite has ceased to be present (at any rate in sufficient numbers to be found in the peripheral blood or to cause appreciable deposit of melanin in the organs), raises the important question as to the possibility of the differentiation of parasites, with imperceptible morphological differences, by their toxic or hæmolytic properties.

16. Hæmoglobinuric fever seems to have been fairly common of late in some parts of India. I am collecting information, and have requested the editor of the 'Indian Medical Gazette' to insert in that Journal a series of questions on the subject. Hæmoglobinuria does not occur in kala azar, notwithstanding the great amount of hæmolysis which takes place in that disease.

I regret the length of this report, but the main subject of it, Major Ross's researches, cannot be dealt with in a few words, as they supply a basis for our future operations.

[It is necessary to point out that the word "coccidium" has been used by Major Ross and in Dr. Daniel's report above printed in a peculiar and not readily intelligible sense. "Coccidium" is the name of a genus of Sporozoa established by Leuckart in 1879 for the cell-parasite of the rabbit's liver, called *Coccidium oviforme*, and other allied species. "Proteosoma" is the name given by Labbé to another genus of Sporozoa parasitic in the blood-cells of birds. When Major Ross states in his report, dated May 21, 1898, that certain "parasites are a development in the mosquito of Proteosoma in birds; and to judge from their structure and mode of growth so far as yet observed, I take them to be *coccidia*," he is using the generic term "coccidium," to describe some phase in the growth of the species of a distinct genus, Proteosoma.

Apparently, what Major Ross intends to indicate by the term "coccidium" is an ovoid firmly walled corpuscle which increases in volume from about 1/2000th inch in length to four or five times that size, and then breaks up into a mass of filiform spores radiating from a central granular mass.

In this mode of spore formation these bodies have resemblances to the true coccidia, which present themselves not only as oviform corpuscles but as cysts with sickle-shaped or filamentous spores. It is, however, not legitimate to apply the generic term "coccidium" to a phase of growth of another genus.—LISTER, *Chairman of the Malaria Committee.*]

"The Malarial and Blackwater Fevers of British Central Africa." Being a Report to the Malaria Committee of the Royal Society. By J. W. W. STEPHENS, M.D., and S. R. CHRISTOPHERS, M.B. Received December 10, 1899.

The parasite found in these fevers belongs to the æstivo-autumnal type, and so far we have not seen in any case the simple tertian or quartan parasites.

In the examination of fresh blood films the parasite is seen either:—

(1) As an unpigmented body which, from its earliest to its latest phase in the peripheral circulation, presents no trace of pigment. We have never observed the brown shimmer (einen braünlichen Schimmer) mentioned by Koch in his description of the parasite found by him in cases of malaria in German East Africa. Or

(2) As a body which in quite early stages presents one or two or more pigment grains, easily discernible; and these may show motility.

For staining purposes we employed either—

(1) A solution of gentian violet, freshly prepared by adding a few drops of the saturated alcoholic solution to a watch-glassful of water. This solution stains the parasites and the leucocytes very deeply, in half a minute or less; and frequently leaves the red cells almost completely unstained, or only a faint yellowish-brown, and does not form precipitates. The films are previously fixed in a mixture of equal parts of absolute alcohol and ether.

Or (2) With a solution of hæmatin (a modification of Thin's formula)—

Hæmatin	2 grammes.
Alcohol (90 per cent.) ...	50 c.c.
Alum	50 grammes.
H_2O	1000 c.c.

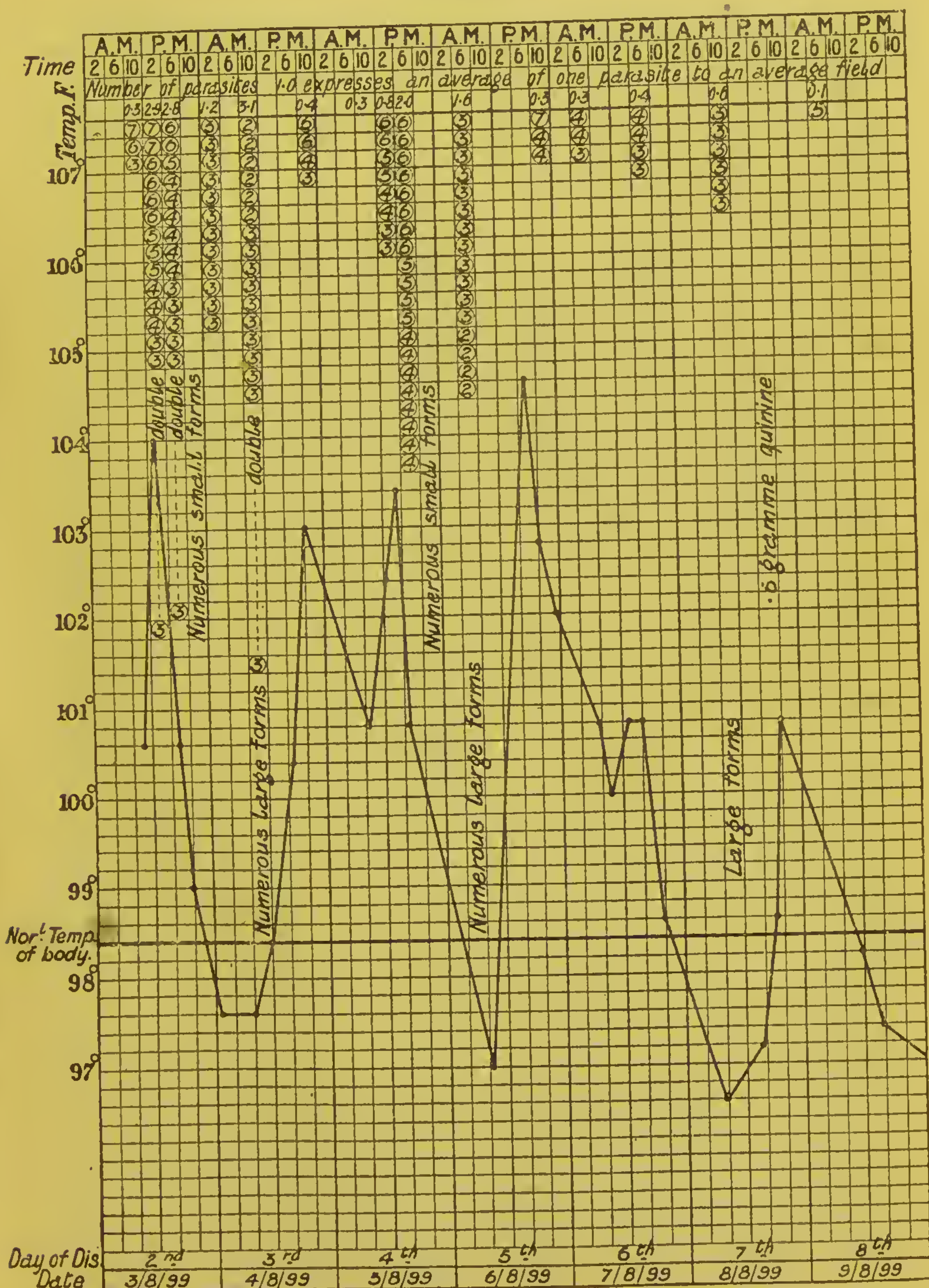
This solution gains in rapidity of staining power by keeping, and is very active when it has deposited a fine precipitate on the sides of the bottle. We have not (as practised by Thin) subsequently washed in alum solution.

Films after previous fixing are left in this solution for five minutes or longer, according to the age of the solution. The necessary time has been reached when the film has a faint brown hue. If now on examination the nuclei of the leucocytes are well stained, it will be found that the parasites also show clearly.

The nuclear networks are stained with a beautiful sharpness and clearness, while the cell body is untouched; so that, for instance, in the large mononuclear leucocytes pigment grains in the cell body can

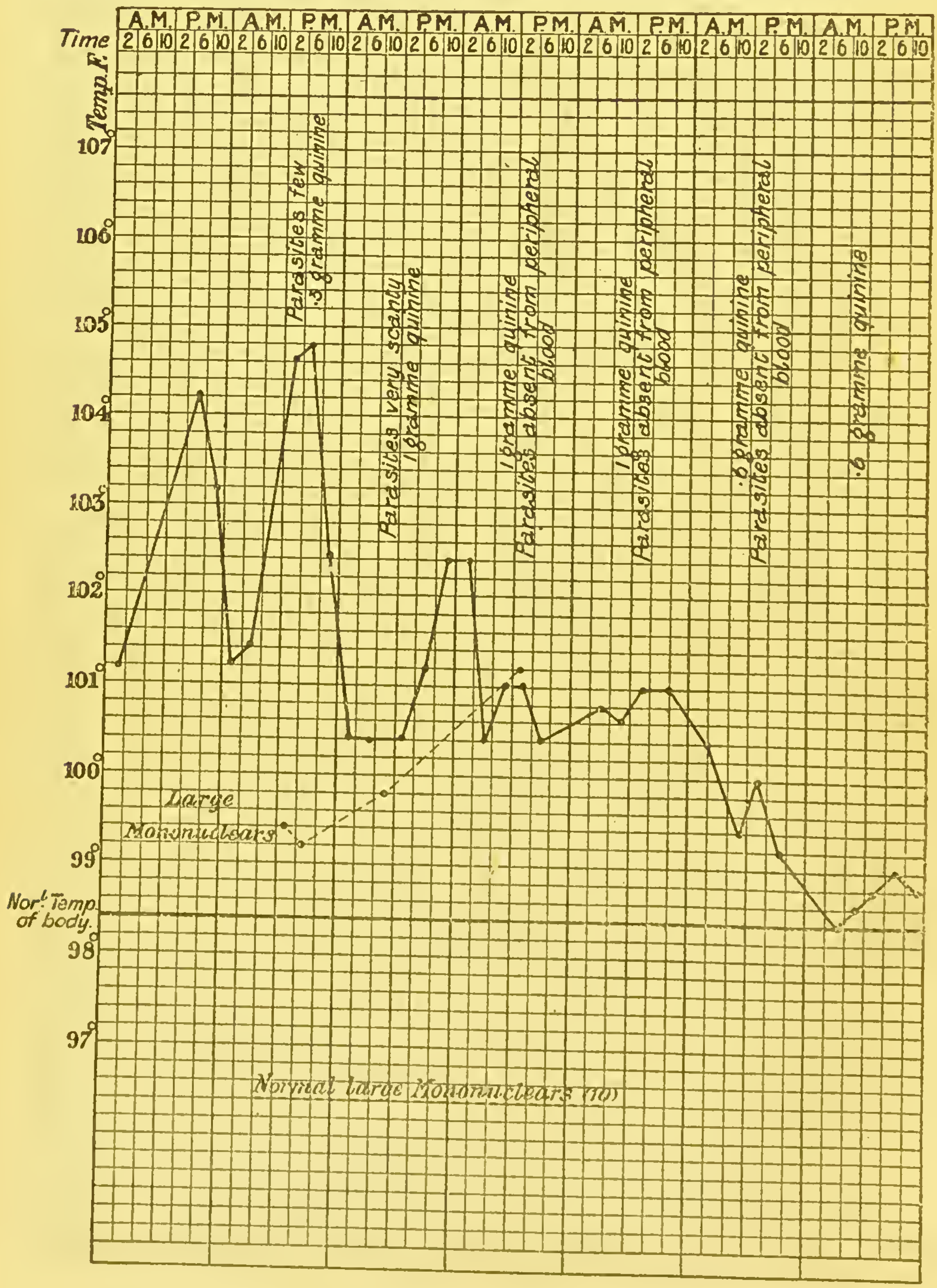
be seen with great distinctness. The red cells, if the specimen has not been overstained, take on a faint greyish-brown colour, against which the parasites stand clearly out. The different parts of the parasite, moreover, stain in different grades of intensity. This method being easy and rapid and giving delicate details of structure, we have made much use of in routine examinations. It further has the great advantage that it does not stain vacuoles as methylene blue does.

Chart I.



The parasite in the youngest form that we can distinguish appears as a minute ring of delicately staining matter, surrounding a space which even at this stage can occasionally be seen to be of a different refraction from that of the external red cell body. Its diameter is equal to one-tenth to one-eighth that of the red cell. The parasite when it has reached a diameter of one-sixth to one-fifth already shows further structures. Thus, in addition to the delicately stained ring

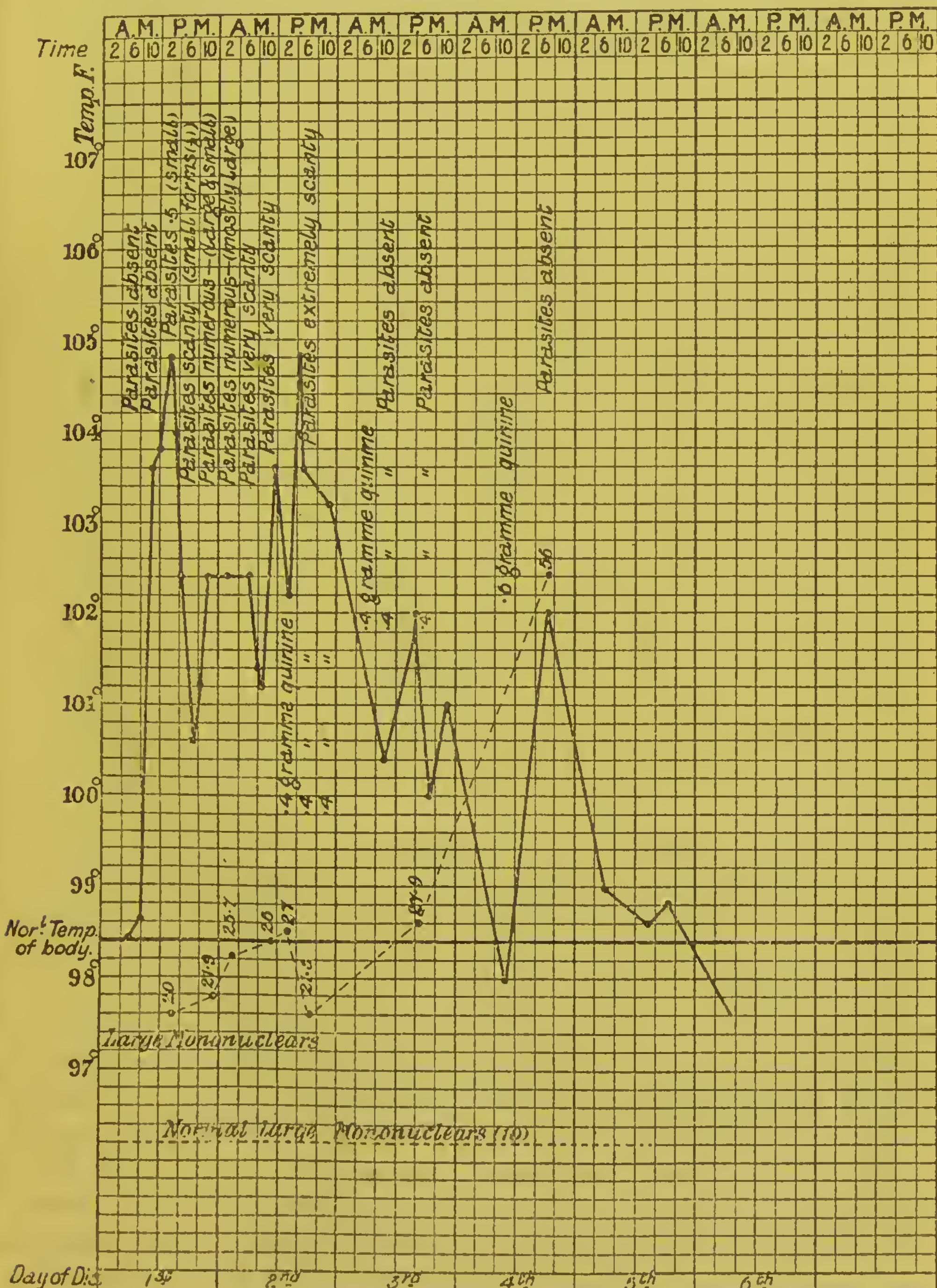
Chart II.



(chromatic substance), we find a deeply stained body (chromatic body) somewhere on the periphery of the ring; and also one or more minute particles (chromatic particles); these also stain deeply.

The central achromatic substance at this stage is sharply defined, by its white refraction, from the dull grey of the red cell. The chromatic body has the appearance of being applied to the side of the parasite; its shape is variable, it may appear as a small particle or rod, and

Chart III.



frequently it consists of two closely allied portions. Though most frequently at the margin of the parasite, yet it may be found in the centre of the achromatic area, free from any connection with the chromatic substance.

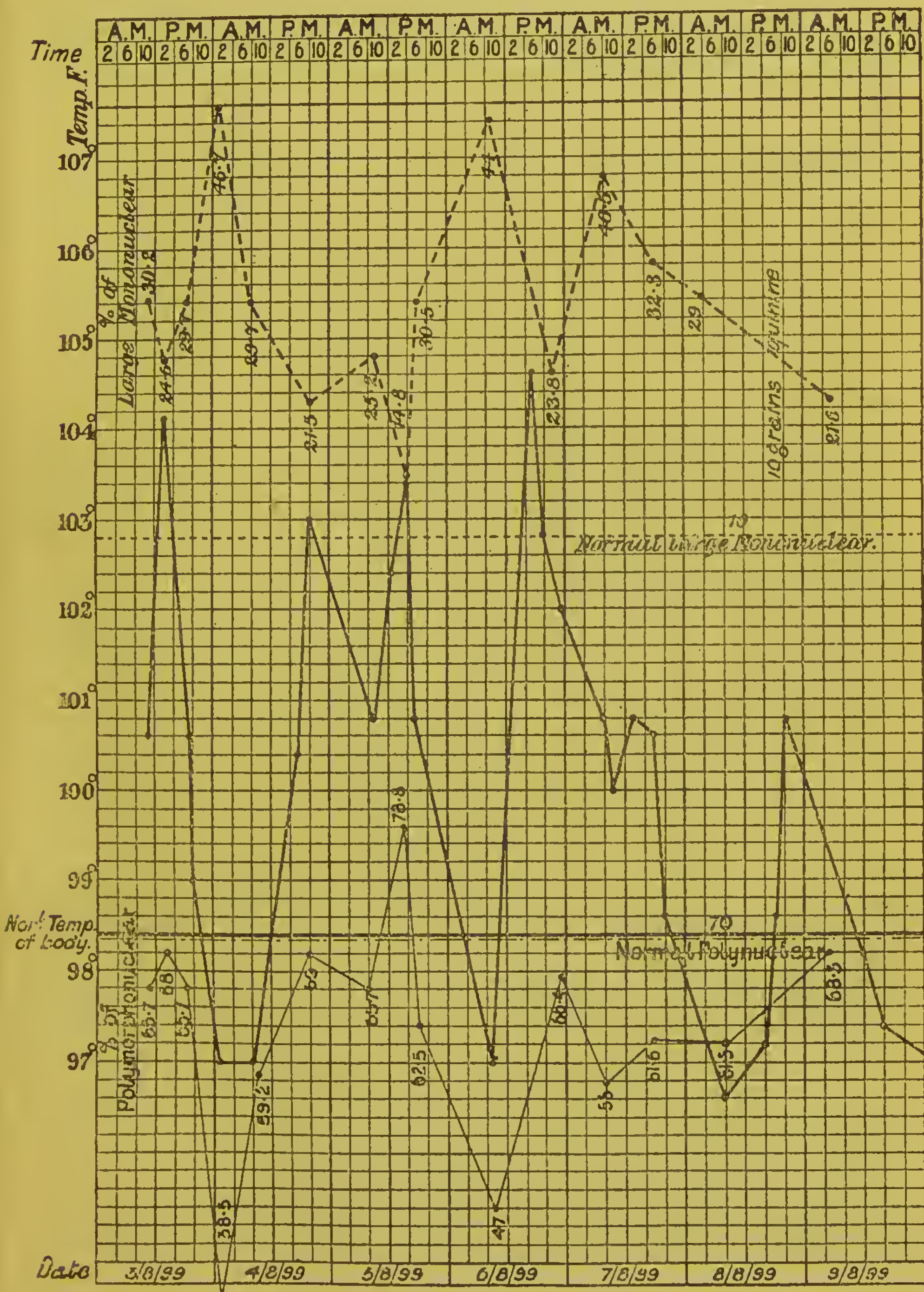
At this, or a later stage, it is seen that the parasite may be applied to the red cell (*accolé*). Parasites either clearly project beyond the rim of the corpuscle to the extent of one-fourth to one-third of their own diameter, or, what is more common, the parasite in optical section appears as a deeply stained body applied to the circumference of the red cell. At other times, in addition to the external portion, there is an internal feebly staining concave portion.

As the parasite increases in size, and is now one-fourth to one-third in diameter, we observe an increase in the amount of chromatic substance; and this mainly at one part of the circumference, giving the parasite an oval shape. In this chromatic portion we observe, now or even earlier, generally two, sometimes more, minute unstained areas. These very commonly occur in juxtaposition in the centre of this lateral expansion. It is mainly owing to this lateral expansion that the parasite further increases in size, until it has attained to one-half to two-thirds in diameter. The parasite then at this stage consists of a central achromatic area, a chromatic body, and a laterally developed chromatoplasm. It is in this much developed lateral area of chromatoplasm that we can observe further signs of differentiation of structure. This takes the form of a division of the chromatoplasm into two or more triangular or crescentic bodies. In the centre of these are situated the unstained areas mentioned above. When two of these bodies occur they are not uncommonly arranged symmetrically, with their bases applied to one another. The arrangement may, however, be irregular, and again one body may stain more deeply than another. At other times this arrangement cannot be satisfactorily made out. Whether or no it possess any developmental significance we cannot at present assert.

The typical appearance of the parasite at this stage is an oval body. As the parasite reaches one-third in diameter the chromatic body is more frequently found encroaching on the achromatic area, and is now often central in position. The chromatic substance is accumulated at a pole. The parasite now presents itself as a long oval body one-half to two-thirds in diameter; and the accumulation of chromatoplasm has occurred to such an extent at one pole that around the achromatic area very scanty staining material is left. The parasite appears to undergo still further changes in the peripheral circulation. Thus we find that the chromatoplasm, which hitherto has stained comparatively faintly, now shows deeply staining areas in its outer portion, and the achromatic area may become so encroached upon as almost to disappear. The chromatic body may still persist, but in certain instances it appeared to be

merged in this large development of chromatic substance. Still further we find that this newly-formed chromatic substance may be divided into three or more portions.

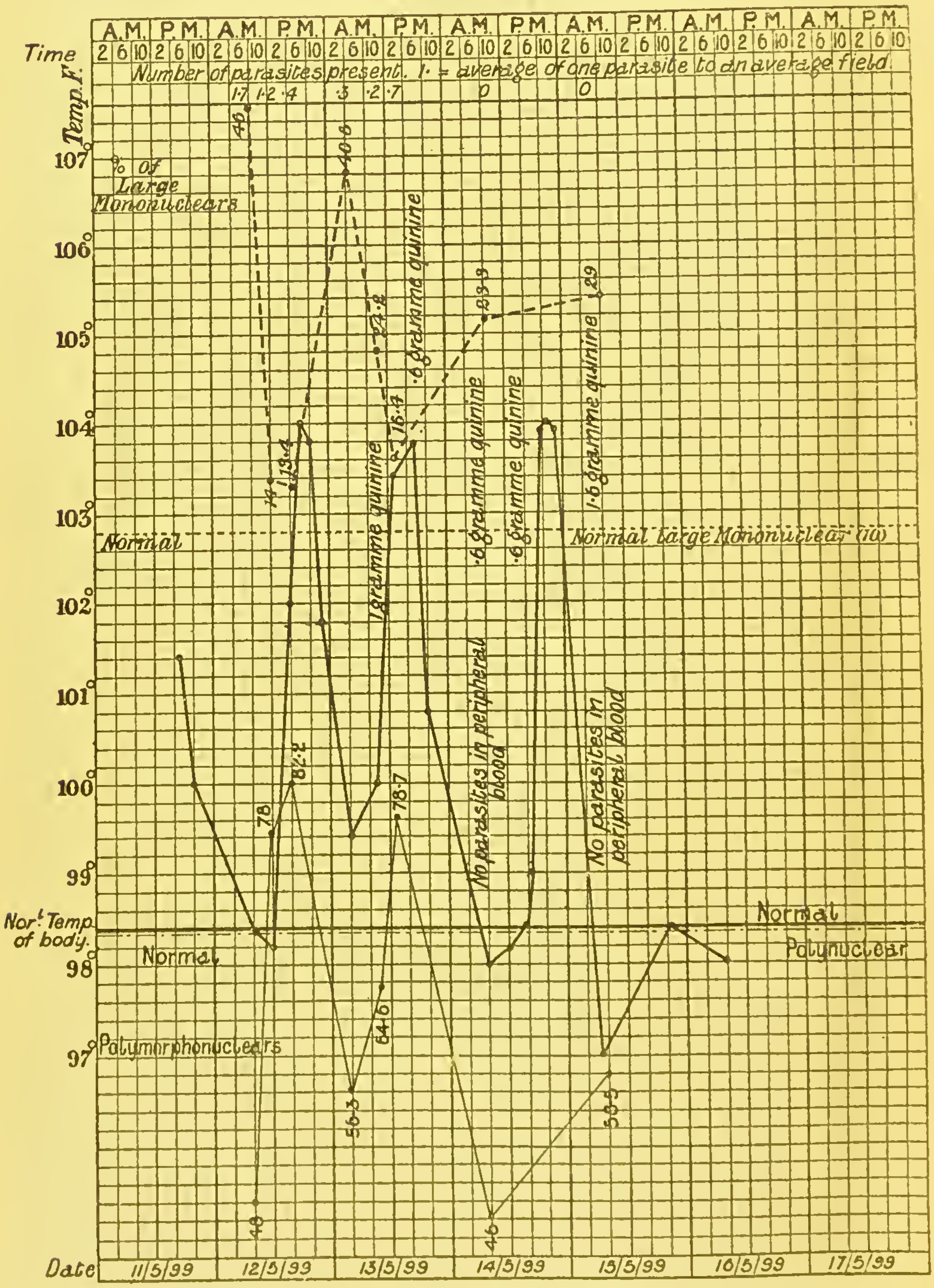
Chart IV.



The fully developed parasite, it has been noticed, often lies in a vacuole in the red cell. The corpuscles containing these developed parasites themselves show alteration in staining property. They

present minute clefts or spots scattered over the cell, staining slightly with hæmatin; they are most numerous in the immediate neighbour-

Chart V.



hood of the parasite itself. This appearance is, however, quite distinct from what is seen occasionally in red cells not containing parasites, but which show a cuneiform punctate appearance, probably constituting the so-called basophil degeneration of other authors.

In our experience the parasite does not, as a rule, develop pigment, even in its latest stage, but in those cases where we have seen pigment in quite young forms, we have been unable to distinguish any other morphological points of difference. Whether this implies the existence of two distinct parasites, we cannot as yet determine, for, in fact, in certain cases, where on one day the majority of the parasites appeared pigmented, on the following day the majority were unpigmented.

I. *Malarial Fevers.*

We may now consider the characteristics of these fevers under the following headings:—

1. Character of the temperature curve.
2. Relation of the parasite thereto.
3. Variations of the leucocytic elements.
4. Pigmented leucocytes.
5. The action of quinine.

1. *Character of the Temperature Curve.*—The uniformity of the temperature curves is sufficient to allow one to deduce a curve typical of the malarial fevers generally encountered.

In a case uncomplicated by quinine, existing for some days, the tertian character is well seen in the fall to normal, or generally below normal every third day; while on the alternate days the fall is approximately to 100° F. only (*vide* Chart I). We have thus between the two subnormal portions a curve which is characterised by an extremely rapid rise followed by a depression, then a rise, and finally a critical fall. The portion of the curve between the subnormal loops we may consequently regard as characteristic of a single febrile attack. In fact, the curve differs in no essential point from that described by Marchiafava and Bignami for malignant tertian fevers (*vide* Chart I).

This curve can be frequently detected even in cases complicated by quinine.

In other cases, especially perhaps in first attacks, the curves are most irregular, and we have been unable at present to ascribe to them any definite course.

2. *Relation of the Parasite to the Temperature Curve.*—We find that the period taken for the parasite to develop from the smallest to the largest size found in the peripheral blood is about eighteen hours, while the remainder of the forty-eight hours is passed in the internal organs (*vide* Chart I).

Again, if we reckon the period between two appearances of small forms or of large forms respectively, in both cases it is one of forty-eight hours (approximately).

The estimation between two periods of small parasites is more easily made at that point of the curve where they are most numerous. At

the summit of the curve the young parasites may be scanty, yet in certain cases there is a large outburst at the commencement of the crisis; it is at this point that the estimation is most easily made.

In many cases parasites at different stages of development can be found at any given point in the curve, but even in these cases there is always a preponderance of parasites of a particular size at particular times.

The fact that parasites of different ages exist at any particular time has led to the view that the time of development of the parasite is a very variable one; from twenty-four hours or less to forty-eight hours or more, but we think this may equally well be explained by a constant time of development with an inconstant output from the internal organs of young forms, which would naturally give parasites of different sizes in the peripheral circulation at the same time.

The distribution of parasites, especially the occurrence of numerous large forms in the apyretic period, and comparatively few small forms during the pyrexia, is a marked feature.

3. *Variation in the Leucocytic Elements.*—We observed, as has been done by several authors, the change in the proportion of the respective leucocytes in malarial fever. We determined to examine more closely than, as far as we know, has been done, the exact character of these changes, especially as we had reason to believe this might aid us in the investigation of the nature of blackwater fever.

It soon became evident that the variations in the leucocytes followed closely the variations in the temperature curve. Here again the variations are most easily observed in regular curves of the tertian type to which we have above referred, though similar changes are indeed to be observed in the majority of charts.

As far as our observations on the total number of leucocytes have extended, the diminution (which is frequently below 2000 per c.mm.) is constant throughout the temperature curve, but the change in the relative proportion of the constituents shows regular fluctuations.

The change consists especially in an increase in the large mononuclear elements, accompanied by a decrease in the polynuclear and small mononuclear. This change is most marked during the periods of apyrexia, and particularly in the normal or subnormal periods of intermittence.

Immediately succeeding the fall of the temperature, the mononuclear leucocytes may increase to such an extent, as to equal or outnumber the polynuclear. From this point the increase falls away, until there occurs a sudden interruption due to changes coincident with the ensuing febrile attack.

Should, however, an ensuing rise not occur, but the temperature remain normal, then there is a gradual decrease in the mononuclear elements until the normal relation is again reached.

As the temperature rises, the relative proportion of the apyretic period undergoes a sudden change, the polynuclear elements now reaching their normal value. This normal proportion continues during the pyretic period with a slight disturbance during the precritical notch, but otherwise the normal relation is retained during the pyrexia until again there is a sudden large mononuclear increase after the crisis.

Examples of this cycle are the following (*vide* also Charts IV and V) :—

4. 8. 99	1 A.M.	97·6° F.	Large mononuclear	46·7
			Polynuclear	38·5
	8 A.M.	97·6	Large mononuclear	29·7
			Polynuclear	59·2
	5 P.M.	99·4	Large mononuclear	21·5
			Polynuclear	69·0
5. 8. 99	9 A.M.	100·8	Large mononuclear	25·2
			Polynuclear	65·7
	3 P.M.	103·4	Large mononuclear	14·8
			Polynuclear	78·8
	5 P.M.	100·8	Large mononuclear	30·5
			Polynuclear	62·5
6. 8. 99	9 A.M.	97·0	Large mononuclear	44·0
			Polynuclear	47·0

In some cases the mononuclear increase is apparent during the pyrexia, the polynuclear increase not being adequate to cause the return to normal. We thus may have a varying mononuclear increase throughout the course of the fever; but even here the mononuclear increase is greatest at the end of the febrile period (*vide* Chart VI).

In other cases we have a polynuclear increase beyond the normal during the pyrexial period.

In cases with continuous high temperature lasting several days, we may find no mononuclear increase until the temperature subsides (*vide* Chart III).

In one case where the regular cycle we have described was very apparent, and at a time when the relative proportions of mononuclear and polynuclear elements were 47 and 49 respectively, there occurred (coincident with the onset of pernicious symptoms, access of severe vomiting and collapse) a rapid disturbance of this relation, the proportion now becoming 18 to 80, and this proportion, notwithstanding the subnormal temperature, continued till death six days later (*vide* Chart VII).

What produced this exceptional course, and under what conditions this leucocytic variation may possibly be absent, we do not know.

In the regular curves it is noteworthy that the mononuclear preponderance is found together with the occurrence of the large forms

of the parasite, while the small forms are accompanied by a polynuclear increase.

We have reason to believe this mononuclear increase may, under certain conditions, continue some time after the subsidence of the fever. The significance of this, its possible relation to immunity or to continued infection, we shall further examine when suitable cases present themselves.

In a count of the leucocytes recorded in our previous report, we said that the eosinophil cells had the value of 14 per cent. This value is in excess of what we have found in numerous subsequent counts where the value is usually less than 1 per cent. But occasionally we have met with specimens in which the value was approximately the former.

Some of the cases have occurred at a time when crescents were present in the blood; but the exact relation of this high value to the malarial fever we must leave for future consideration.

4. *Pigmented Leucocytes.*—The occurrence of pigmented leucocytes we have already described. The most characteristic of these are the mononuclear leucocytes containing one to two or more clumps of pigment, and ten to thirty fine grains scattered through the cell body.

These appear to us to be of great diagnostic value; their appearance is absolutely characteristic, and they give a definite proof in the absence of parasites of a recent infection.

Thus in many cases where quinine had caused the complete disappearance of parasites, which we had previously observed, we had still evidence of malaria in the occurrence of these leucocytes.

Pigment also is found in the polynuclear cells in a smaller or greater amount, but we regard the mononuclear cell with much pigment as peculiarly characteristic.

Isolated dots of pigment also are found in the leucocytes, but we should hesitate to make a diagnosis simply on the presence of these. It is perhaps necessary to point out also how easily minute tags of the nuclear network apparently or really detached from the nucleus can be mistaken for pigment. In specimens stained with hæmatin these tags are an almost constant phenomenon.

The detection of pigmented leucocytes may require prolonged search. Their absence must not necessarily lead to a decision against malaria, for our knowledge as to the conditions which bring about their appearance in the circulation is still incomplete. Thus, in a fatal case of blackwater, we had observed numerous parasites and pigmented large mononuclear cells in the peripheral blood. Both these completely disappeared after the administration of quinine; but post mortem in the spleen there were found large numbers of mononuclear leucocytes containing much pigment associated with numerous parasites of a spherical and ovoid type.

5. *Action of Quinine.*—The rapidity and completeness with which even small (*e.g.*, 0·6 gramme) doses of quinine will cause the disappearance of parasites from the peripheral circulation is a most striking phenomenon. Again and again have we examined blood films in cases, presumably malarial, with negative result, and in most of these cases we have found that the patient has been taking quinine. Nor can the absence always be attributed to the cessation of the attack, for the clinical symptoms may not abate, and the pyrexia may continue for days. The case may even terminate fatally without the presence of a single parasite in the peripheral blood. Had such a case come under one's notice subsequently to the administration of quinine, and had one based one's diagnosis simply on the presence of parasites, the conclusion would have been reached that the case was not malarial.

The absence of parasites in the presence of quinine is no proof that the case is not one of malaria. We still, however, have two means of arriving at a diagnosis in cases where the absence is due to quinine.

(1) The presence of the characteristic much pigmented leucocytes (mononuclear).
(2) The leucocytic variation.

Examination for the presence of this diagnostic sign should be made by preference during the apyretic period. An examination made during the pyretic period, if the variation is absent, is inconclusive.

It is true that a similar mononuclear increase has been observed in typhoid fever, but there are other means by which typhoid fever can be diagnosed.

That this reaction is exceptionally absent we have already stated.

II. *Blackwater Fever.*

We do not now propose to discuss the many views that are held as to the nature of this fever. We shall draw attention only to the facts which the five cases we have so far seen we believe establish. We shall allude to these facts under the following categories.

I. *Existence of a Special Organism.*—In all five cases, frequent examinations of the blood failed to show any *special* parasite or organism. In two cases cultures were made from the blood on agar, in both they remained sterile. In one case cultures were made from the spleen and heart's blood; in both pure cultures of *Staphylococcus aureus* resulted. Cultures made from the bile of the same case remained sterile. In case II which we have already reported, no micro-organisms or *special* parasites were found in the organs post mortem.

II. *Relation to Malaria.*—In discussions on blackwater fever, considerable stress is laid on the presence or absence of parasites. It is urged by some that their absence is due in most cases to the fact that

quinine has been taken, but no further evidence has been adduced by such observers in support of their view, that such cases without parasites are malarial. We have shown above, however, that two methods of proof still exist in cases where parasites are absent owing to the administration of quinine, these are namely : (1) The presence of pigmented leucocytes; (2) The leucocytic variation.

In all our cases parasites were absent, and in all quinine had been taken. In one case we had not the opportunity of applying the further means of diagnosis to which we have drawn attention.

The remaining four we shall show are in direct relation to a malarial infection.

Thus in case III the hæmoglobinuria occurred during the course of a typical malignant tertian fever, in which very numerous parasites were found previous to the blackwater and none subsequently.

In cases II, IV, V, no "intracorpuscular" parasites were at any time seen. (In case IV crescents were seen but they were extremely rare). In all, however, both pigmented leucocytes and the leucocytic variation occurred, so that, in spite of the absence of parasites, we feel justified in classing these also as malarial.

In two cases the diagnosis made solely on these grounds received additional confirmation, in one case from an examination of the organs (Case II, Report I), in the other by an occurrence, seven days after leaving hospital, of a severe malarial fever with numerous parasites. We are of opinion that in this case the patient was not exposed to the possibility of fresh infection. Had we relied then simply on the presence of parasites as a proof of malaria, we should have been unable to assign such an origin to three of our cases; but by these subsidiary means of diagnosis we have been able to class them all as malarial.

III. *Relation to Quinine.**—In all our cases the patients had taken quinine previous to the onset of hæmoglobinuria.

The intervals between the taking of quinine and the hæmoglobinuria were as follows :—

Case I.—Two doses of 0·3 gramme five and two hours respectively.
Case II.—The interval could not be determined.
Case III.—Twenty-three hours.
Case IV.—Ten hours and in a recurrence six hours.
Case V.—Seven hours.

These cases, and especially Case IV, in which a relapse of blackwater

* In procuring histories from patients; whether or no they had taken quinine, when they had their last malarial attack, whether they had been bitten by mosquitoes, &c., we have experienced great difficulty in arriving at the truth. We have no hesitation in discarding as valueless all statements which have not been submitted to rigorous cross-examination. We have found that patients and others are only too ready to volunteer statements which on close inquiry are found to be absolutely baseless.

seemed very definitely to follow the administration of quinine, seemed to us to lend support to the view held by several authors who attribute the onset of blackwater to quinine. We therefore endeavoured to ascertain if experiments in vitro could produce similar phenomena, but they have yielded negative results.

1. Thus we endeavoured to show the presence of a hæmolytic toxin in the hæmoglobinous urine. On our own blood it had no such action, we regret that we did not try the experiment on the patient's blood.

Nor did the serum of the patient, Case IV, hæmolyse our own blood, nor although the urine contained hæmoglobin for twelve hours after the experiments were made, did the patient's serum show any hæmoglobin on separation from the blood clot.

2. We endeavoured also to ascertain if any change in the resistance of the red cells existed, but this was also negative. Thus the isotonic point of the patient's blood and our own was identical.

Observations were made subsequently to a first attack, previously to, during, and subsequently to a second attack. These results are not conclusive, however, against the view that the resistance is lowered, for the less resistant corpuscles may already have been destroyed.

3. We next determined the resistance of the corpuscles to quinine solutions.

Thus 1 gramme of quinine hydrochlorate was dissolved in 21·4 c.c. of 1 per cent. saline by heating. On cooling, crystals separated out. The remaining solution was then diluted with 1 per cent. salt, so that in a series each dilution contained half as much quinine as the preceding tube. To each series was then added (1) patient's blood, (2) normal blood.

Patient.	Original solution hæmolysed.	1st dilution hæmolysed.	2nd dilution clumped.	3rd dilution clumped.	4th dilution clumped.
Normal.	Hæmolysed.	Hæmolysed.	Negative.	Negative.	Negative.

The *hæmolytic* action of quinine in vitro is thus the same for the patient's blood as for normal blood.

The action of quinine in solution in serum was also tried on the patient's blood. At a time when presumably the administration of quinine might bring about hæmoglobinuria, one of us took 2·0 grammes of quinine, and when subjective symptoms were pronounced, blood was taken and the serum allowed to separate. To this serum the patient's blood was added, but the result was again negative.

Though we have been unable to show in vitro any alteration in

tonicity or increased susceptibility to quinine of the blood of a blackwater patient, yet in reference to the view that quininc does exercise such hæmolytic action, we may suppose that it is unnecessary to ascribe any such direct action to quinine itself, but that rather by its lethal cffect on the parasites a sufficient quantity of toxins from their protoplasm is liberated to bring about the hæmoglobinuria.

These experiments we have only had the opportunity of applying in one case, and they will necessarily require repetition and modification before we can deduce conclusions from them.

Since our return to England we have had a opportunity of seeing Professor Koch's report on blackwater fever. He finds that in twenty-three out of forty-one cases there were no parasites present, and that in thosc cases where present the rule was to find few. This it seems to us is explained by the fact that in all cases quinine has previously been administered.

No statement is made as to the presence or absence of pigmented leucocytes in the blood, nor is it explained what the nature of the "fever" or malady was that induced the patient to take quinine.

Further in the post mortem records no examination of the brain appears to have been made.

To our five cases may be added two, the organs of which have been sent us by Dr. Todd of Umtali and Dr. Elmslie of Bardawe respectively, in both these the spleen showed large deposits of black pigment, the other organs we hope to examine shortly.

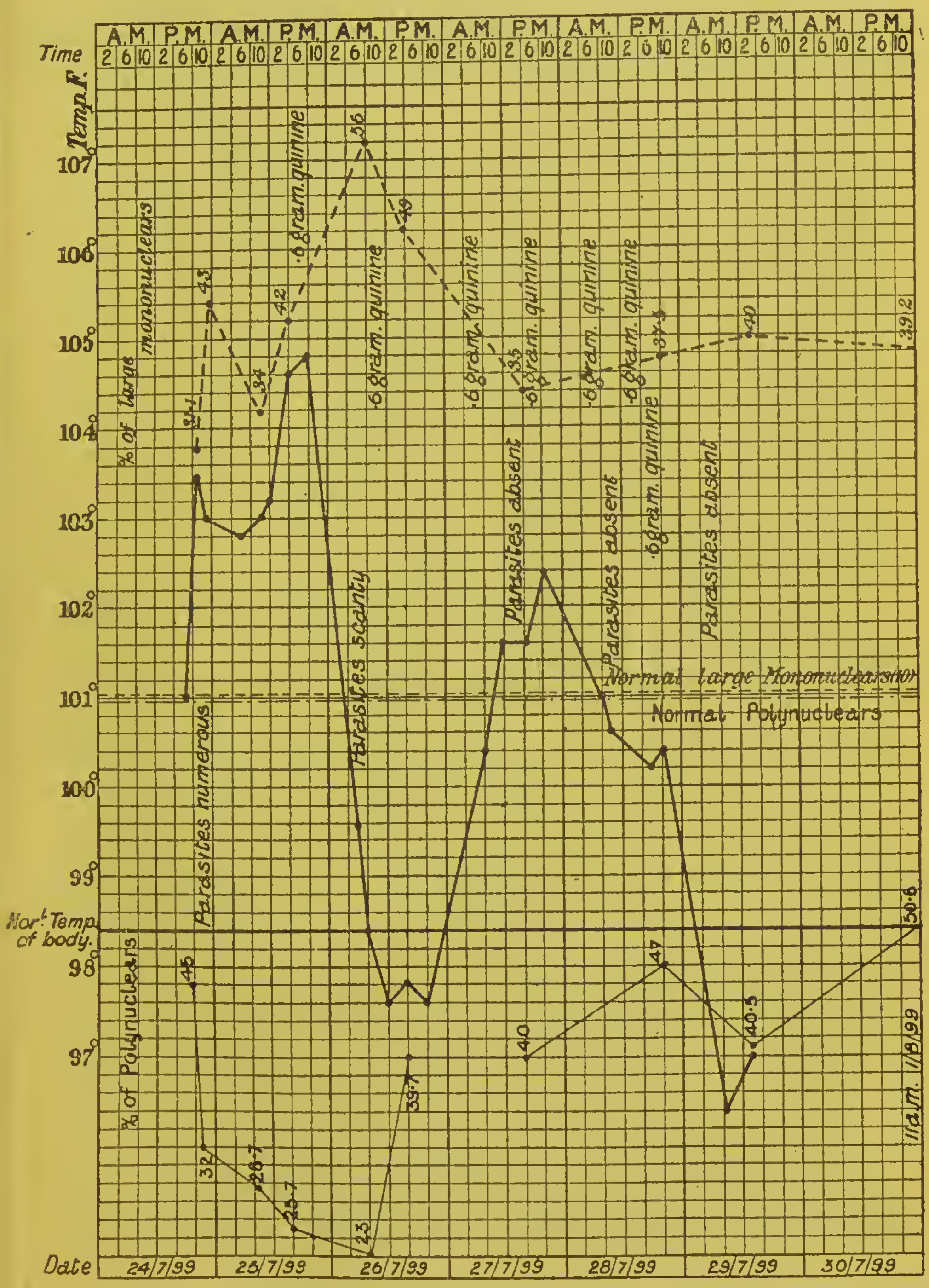
So that to sum up, we have seven cases of blackwater, all of which show a malarial infection, though of the five cases wc saw during life only one showed parasites. It is necessary then to determine how many of these cases without parasites are really malarial.

Case I.—H., a plasterer, living thirteen miles from Blantyre, arrived in country February, 1896. Had febrile attack January, 1899. February 6th, 1899, 4 P.M. feeling cold and unwell, took 5 grains of quinine; 7 P.M. took 5 grains again. 9 P.M. passed an ordinary quantity of deep red urine; the specimen showed Hgb and red cells. 12 P.M. passed more, lighter. 5 A.M. February 7th more, still lighter. February 7th patient admitted to hospital. No Hgb was found in the urine, temperature normal and patient feeling quite well. No recurrence of symptoms. Numerous examinations of the patient's blood in the fresh condition were made and no parasites were found.

Case II.—J.R., age 28, engineer. Came to B.C.A. in August, 1897. Except for a few months spent at Chinde, he has been living at Inpimbe in a mud and wattle house on the bank of the Upper Shire river. He has not had fever previous to living in this country. Whilst at Inpimbe he has had occasional slight attacks of "fever."

Chart VI.

Case I.

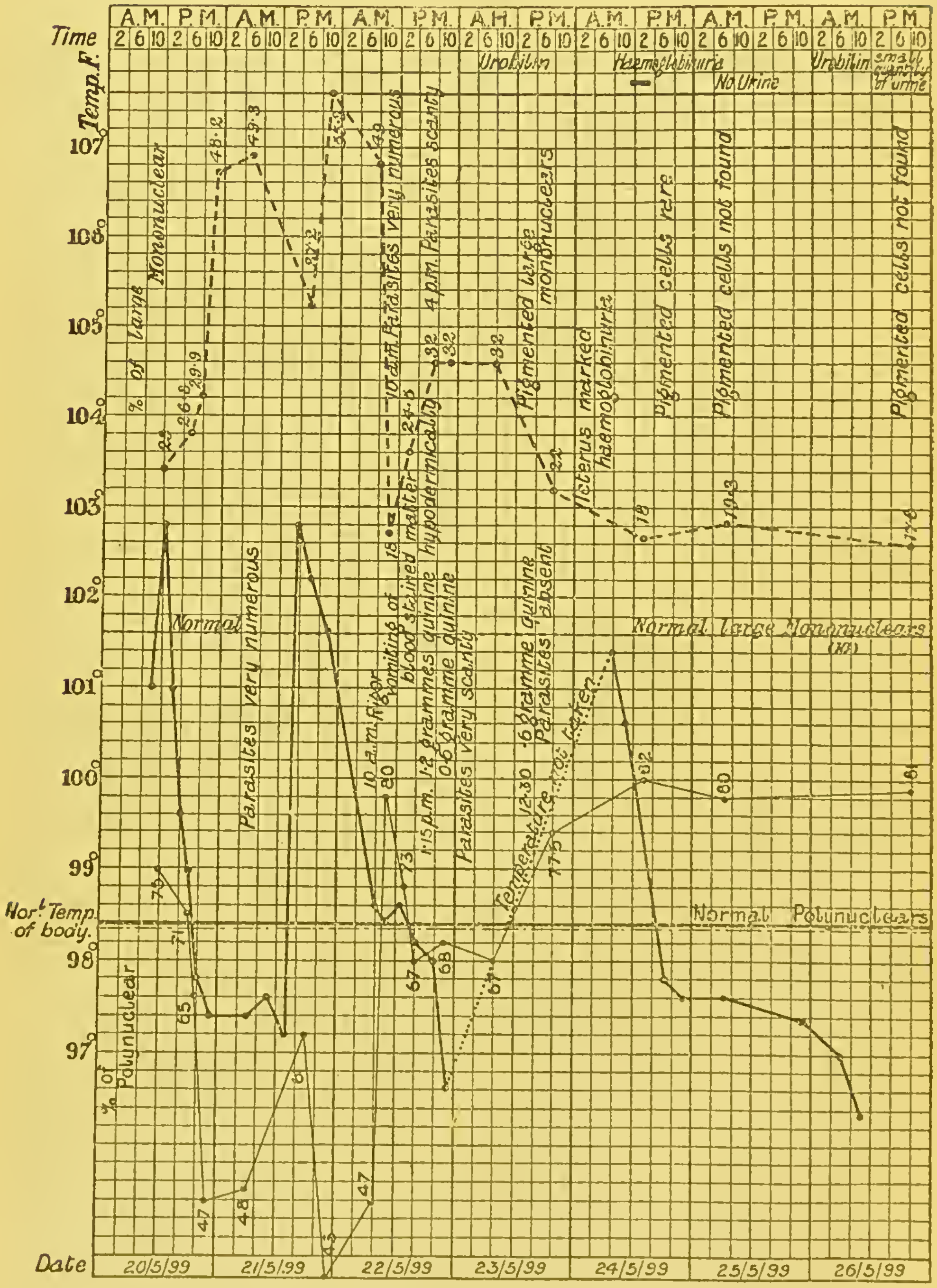


For a week previons to the attack of blackwater, he complained of being out of sorts. On the morning of 18th March he took 5 grains of quinine. At night his temperature was 102°. Next morning he took 10 grains of quinine. At 4 P.M. his temperature was 103°.

About 2 A.M. on the 20th he was suddenly seized with severe vomit-

Chart VII.

Case II (*vide* also Chart X).



ing. Three hours later he had two severe rigors at an interval of half an hour. Next morning his urine was black.

Dr. Grey, who arrived at midnight of the 20th, states that during the 21st and 22nd the most prominent signs were—

1. A temperature of above 100°, rising about midnight on the 20th and 21st to 104°.

2. The passage of an extremely small quantity of urine (2ʒ since his arrival). The urine was of a dark mahogany colour.

3. A pronounced yellow coloration of the skin, first seen on the morning of the 21st, and afterwards fading so that shortly before death there was only a faint trace upon the legs.

4. Frequent vomiting. At first of bright green vomit, later of dark grumous material.

5. Marked hiccough occurring frequently throughout the illness.

6. An enlargement of the spleen, so that it could be felt three fingers' breadth below the costal margin.

Twelve hours before death the fresh blood showed no parasites. The red corpuscles were enormously reduced in number, being only 795,000 per c.mm. The hæmoglobin was reduced to 30 per cent. of normal. Leucocytes were 10,000 per c.mm.

Up to five or six hours before death patient was quite clear mentally, after that he became delirious and semi-conscious. Some hours before death his respirations which had been twenty-six per minute gradually increased to forty-eight per minute.

Death took place shortly after a convulsion at 5 A.M. on the 23rd. One hour before death the red corpuscles were 760,000 per c.mm.

A partial autopsy was made one hour after death.

The following were the chief features:—

Tissues were very pale—fat very yellow—blood extremely thin, dark and fluid.

Liver was slightly enlarged—smooth. It contained a large amount of blood which flowed freely on incision. Substance of liver was pale and rather waxy looking.

Spleen was enlarged, measuring 7 inches in long diameter—firm in consistence—no evidence of perisplenitis.

Kidneys were slightly enlarged—the capsule was adherent in patches. There was no marked congestion. On passing a knife over the cut surface a brownish fluid resembling the urine was expressed, but no visible blood. The cortex was dark brown and soft in consistence.

Stomach was contracted—there were no petechiæ.

Intestines appeared normal.

Bladder was empty and contracted.

Red marrow was normal in appearance.

The thorax and brain were not examined.

Examination of Blood-films, Urine, and Sections of Organs.

Blood.—The patient was first seen on the 21st March, 1899, early morning, twenty-four hours after onset of acute symptoms. Films were taken at four-hour periods (and sometimes more frequently) from this time till death on 23rd, 5 A.M. The red cells in these specimens

were normal in appearance. No nucleated red cells were seen. The leucocytosis was a marked feature, so also the large quantity of platelets.

Although in none of these specimens could we detect parasites, yet there was evidence of a recent malarial infection in the presence of pigmented leucocytes in the films taken on the 21st, 22nd, and 23rd respectively. The pigment was black, occurring in coarse spicules and also in finer granules, and, as far as we can judge, is identical with malarial pigment.

The leucocytic variation will be seen on reference to Chart X.

Urine.—Dark, brownish-red in colour, depositing a dark-brown, granular sediment on standing. Hgb = 20 per cent. of normal blood. No met. Hgb. The oxyhæmoglobin bands gave the reduced spectrum of Hgb on addition of Stokes's fluid. Boiled with soda, on cooling, the urine gave deep hæmachromogen bands, indicating, probably, the existence of reducing substances in the urine.

Much albumin. No bile pigment. Pavy's fluid showed reducing bodies.

The sediment (centrifugalised) consisted of a large quantity of brownish-yellow bodies 1—7 μ in diameter; also minute granules. They are also seen in the collecting tubules of the kidneys, and are probably identical with "granular cast" material. No red blood cells. There was much granular epithelium stained yellowish.

Torula, micrococci, and bacilli were also present.

Sections.—Sections of kidney, liver, spleen, and bone marrow have so far been examined.

Sections in paraffin were stained with methylene blue, gentian violet, and Bright's stain for micro-organisms; but, so far, no evidence has been obtained of their existence in the tissues (cultures from the organs in the fresh state were not made). The pathological changes shown in the tissues are as follows:—

Spleen.—Films of splenic pulp, stained in various ways, showed no evidence of the existence of malarial parasites or crescents. There were present, however, here also numerous pigmental leucocytes. Paraffin sections.—

The blood in the sinuses showed no parasites, but numerous bodies having the character of platelets. By Bright's stain long masses of fibrin were seen. The most characteristic appearance was the deposit of pigment. It occurred chiefly in the cells of the splenic reticulum. Secondly, in large cells with nuclei, staining feebly and diffusely (macrophages). The contents of the latter included also granular *débris* (eosinophil) and red cells. Thirdly, in large mononuclear cells. The pigment possesses a greenish-black colour, is often arranged in small, spherical clusters. The pigment granules are surrounded by a clear space. No coarse granules of pigment were seen. Yellow pig-

ment also occurs in small quantity in the macrophages, not exceeding the normal in amount. The dark pigment on the whole remains unchanged by HCl and K_4TeC_{76}. In the macrophages and, to some extent, elsewhere a blue reaction is obtained.

Very little pigmentation was seen in connection with the Malpighian bodies. The spleen was stained further, according to McCallum's method, with watery hæmatoxylin for inorganic iron salts; the result was negative.

There was no amyloid change here or in any other of the tissues examined.

Liver.—The evidences of pathological change were greater here than in the spleen.

The most noticeable changes were :—

(i) Small necrotic foci.

These were situated laterally to the intra-lobular vein, occasionally extending to the periphery of the lobule. The hepatic cells in these areas were much shrunken, and stained badly, and their nuclei were distorted, and stained diffusely.

There was no leucocytic infiltration in the neighbourhood of these areas.

(ii) Small thrombi.

These are found in considerable numbers in the sub-lobular veins. The thrombi show here and there in their substance small pigmented cells.

(iii) Pigment.

It is greatly in excess of that found in the spleen. It occurs in three forms :—

(1) Yellow pigment situated in the centre of the liver cells.
(2) As greenish-black pigment occurring chiefly in large swollen cells lying in the liver capillaries (endothelial); also occasionally in normal endothelial cells. The pigment is gathered into spherical clusters as in the spleen, is frequently surrounded by a clear area. In the swollen endothelial cells the pigment may occur in large spherical masses. Here it is found together with yellow pigment.
(3) In leucocytes in the small blood vessels.

In sections treated with HCl and K_4TeC_{76} the yellow pigment in the liver cells gives a uniform blue reaction; the reaction occurs also in association with the black pigment of the endothelial cells; but in this case there was always much black pigment unchanged. No inorganic iron salts were present (McCallum's test).

Kidneys.—(i) Glomerular changes were absent. Nor elsewhere were there any signs of acute inflammatory process.

(ii) The convoluted tubules showed much change. The cells were

in process of active disintegration, the lumen of the tubule being filled with a granular mass. The cells had lost their striation, were very granular, many of the nuclei also showed signs of degeneration.

(iii) The straight (and collecting) tubules were filled with shed epithelium and masses of granules. The large collecting tubules were also filled with granules resembling, but rather larger than, those seen in the urine.

(iv) Under the capsule were patches of young fibrous tissue with large multinucleated cells containing yellow pigment. No dark pigment was found in the kidneys.

Red Marrow.—There is much pigment in the marrow of the sternum. It occurs (1) in the capillary endothelium; the pigment-containing cells are swollen; (2) in large branched cells of the narrow stroma; (3) in pigment-laden cells (leucocytes) scattered throughout the marrow. In these latter cells yellow pigment is found together with the black, but in the other case the black pigment occurs alone. No parasites were found.

Case III.—Has been two years in B.C.A. The first year was spent at Likoma, Lake Nyassa. He had fever there twice, and also "jaundice." Most of the second year at Mponda's, near Fort Johnston, Lake Nyassa. Had fever there in March, 1898. He had fever at Fort Johnston just before leaving for Blantyre. He was in Blantyre a few days when he was attacked by severe pain in the muscles (of the chest). Two to three days afterwards the present fever developed, and the patient was first seen on 19.5.99.

Up to the morning of the 22nd the fever was of the ordinary tertian character, with numerous parasites.

22.5.99., 10 A.M. Whilst the temperature was falling to normal he became much collapsed, had severe vomiting (the vomit being blood stained) and much shivering. At this time a sudden change took place in the relations of the leucocytes, the great mononuclear preponderance which was accompanying the fall in the temperature curve suddenly gave place to an increase of the polynuclears—a relation which lasted till death.

22.5.99. 1.15 P.M. Quinine was, for the first time, administered, 1·2 grammes being given hypodermically.

10 P.M. 0·6 gramme of quinine hypodermically.

23.5.99. Parasites were very scanty. A small quantity of urine passed in night contained no hæmoglobin.

12.30 P.M. 0·6 gramme quinine.

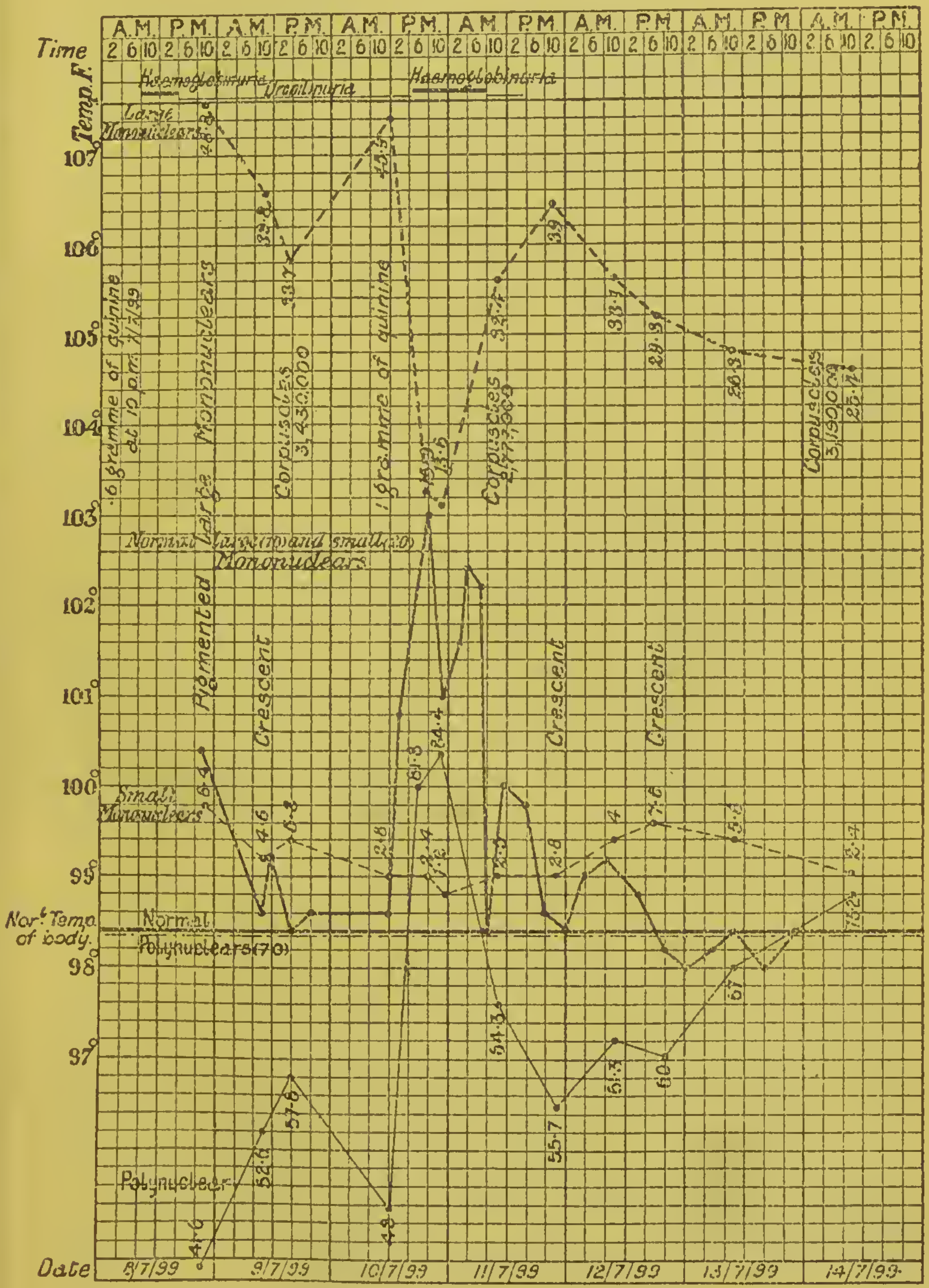
24.5.99. Distinct icterus.

11.30 A.M. Hæmoglobinuria. Parasites absent.

From the 25th to 28th patient became very weak. Icterus was very

Chart VIII.

Case III (*vide* also Chart VII).



marked on the 25th, and continued till death. There was also trouble some hiccough.

27th. Fæces contained blood.

28th. Double parotitis.

Death occurred on the 29th.

Hæmoglobinuria and urobilinuria.—

22.5.99. 7.30 A.M. Urine clear.
1.15 P.M. 1·2 grammes quinine hypodermically.
7 ,, Urine clear.
10 ,, 0·6 gramme quinine hypodermically.
12 midnight. Urine clear.

23.5.99. 12.30 P.M. Urine clear, 0·6 gramme quinine.
During night urine clear.

24.5.99. 11.15 A.M. 84 c.c. Dark urine. Hæmoglobin.
12.45 P.M. 28 c.c. Dark urine. Methæmoglobin granular casts and granular sediment. Attached to some of the casts were small masses of reddish crystals (? hæmatoidin).

25.5.99. No urine passed.

26.5.99. 7.45 P.M. Dirty brown urine. On centrifugalisation, pale yellow. No hæmoglobin. Albumin. Many casts in sediment, some cylindroids with adhering yellow pigment. No bile pigment.

27.5.99. 6 P.M. A test-tube full. Very dark urine, depositing a greenish-black sediment on standing. The sediment consisted of masses of spherical bodies varying in size from the diameter of a red cell to minute particles. They were stained a yellowish-green colour, and had the character of the granules of coarse tube casts. Adhering to the bladder epithelium there was much refractile greenish-yellow pigment. Hæmoglobin absent, much albumin, and no bile pigment.

Blood.—The destruction of corpuscles was not great.

24.5.99. 11.15 A.M. Hæmoglobinuria.

24.5.99. 4 P.M. Red corpuscles 4,000,000 per c.mm.

Leucocytes.—24.5.99. 4 P.M. 22,000 per c.mm.

Up to 10 A.M. on the 22nd, the leucocytic variation was very pronounced. After the attack of vomiting and collapse with fall of temperature, the mononuclear increase gave place to a polynuclear increase, and afterwards continued, but slightly marked, till death on the 29th.

Parasites.—Parasites were present in large numbers before the morning of the 22nd.

22nd. 10 A.M. Large numbers of small forms.

23rd. 8 ,, Parasites scanty.

24th. Parasites absent.

Parasites continued absent till death.

20th—24th. Pigmented, large mononuclear leucocytes present. Rare on the 24th.

25th—29th. Pigmented leucocytes absent.

Autopsy.—Icterus was still present.

A peculiar smell of body and organs was noticeable.

A few small pericardial hæmorrhages present.

Gall bladder contained dark green inspissated bile.

Liver much enlarged. Liver and spleen much pigmented.

In spleen films, large ovoid, and round parasites containing much pigment (some of them intracorpuscular), probably related to crescents. Large numbers of much pigmented mononuclear leucocytes.

No parasites seen in brain films.

The tissues have not yet been examined.

Case IV.—S. had not been in the tropics before coming to B.C.A. Came to B.C.A. in 1895. Spent two years in Chinde, on the coast, without having any fever. He then went to Patima, on the lower Shire river, where he has lived since. He has had about six attacks of fever; none very severe.

On June 24, 1899, he came up the Shire river in a houseboat, and was much bitten by mosquitoes. On the morning of July 5 had a shiver, followed by a rise of temperature to 104°. Late the same afternoon his temperature was 99°. Next day he had another attack, and his temperature taken several times during the 7th was 101°.

At 10 P.M., July 7, he took 0·6 gramme of quinine. At 3 A.M. on the 8th (*i.e.*, five hours later), he had a rigor and vomited. At 8 A.M. on the 8th, ten hours after the quinine, passed about "a pint" of bright red, clear urine (Hgb).

He then travelled to Blantyre, and was admitted to hospital. On admission at 10 P.M., on the 8th, urine was not hæmoglobinous.

During the 9th his temperature was normal, and he was feeling quite well. No parasites were present.

At 11 A.M., on the 10th, the medical attendant gave 0·6 gramme of quinine, and 0·3 gramme at 12 noon. Half an hour after the second dose patient had some tinnitus. At 5 P.M. passed some urine deeply hæmoglobinous. The hæmoglobinuria continued until the morning of the 11th. At this time a slight general yellowness of skin and conjunctivæ was noticeable.

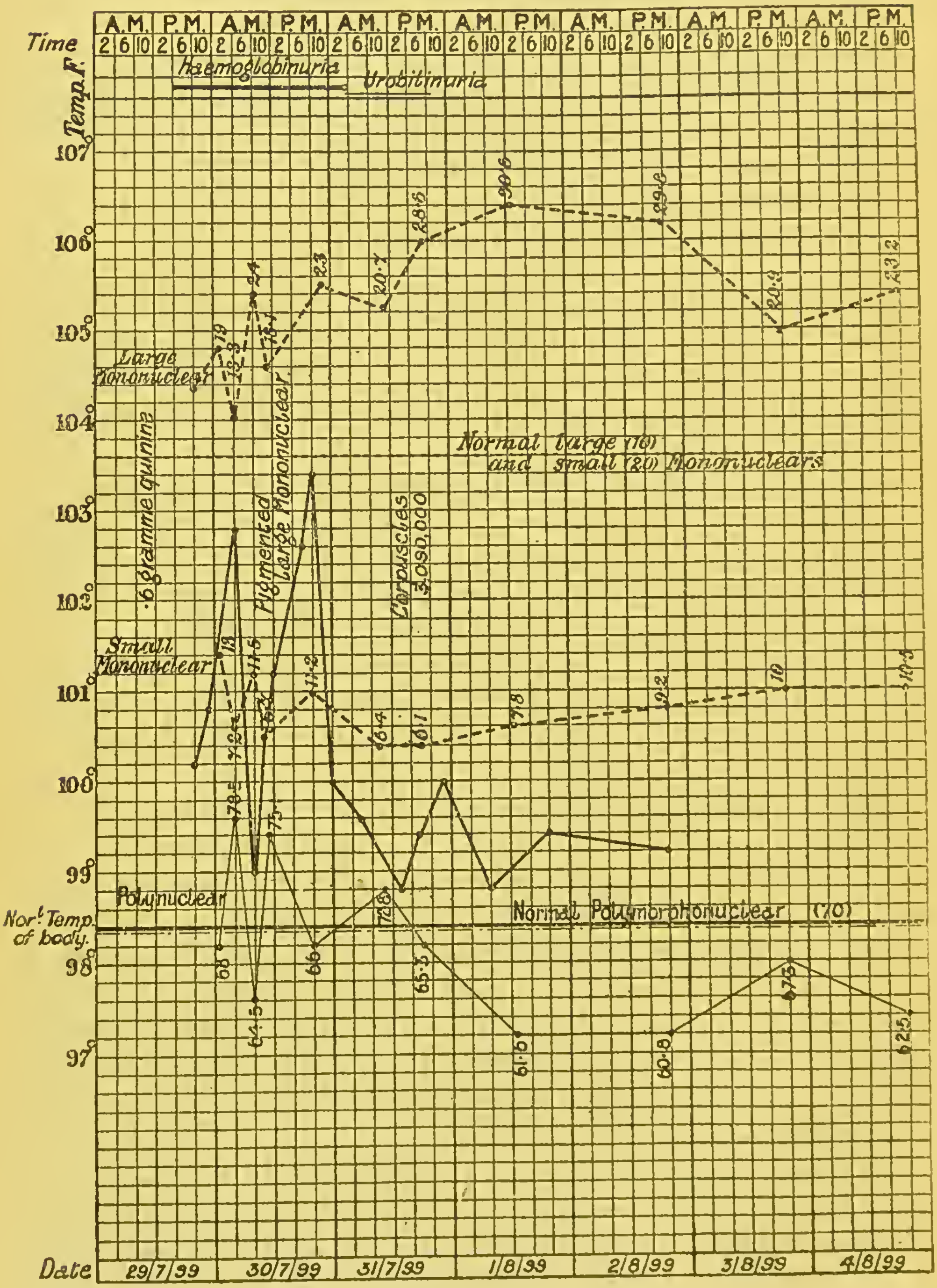
The patient rapidly convalesced, and left hospital on the 22nd. He remained in Blantyre, where exposure to fresh malarial infection was extremely improbable, until the 27th, when he left for the lower river. On the 29th he had a slight feverish attack, similarly on the 30th and 31st. On August 1 had a severe attack of fever, and again came to Blantyre. In hospital at Blantyre he had a severe typical malignant tertian fever, with numerous parasites. He was not given quinine until the fifth day. No hæmoglobinuria resulted.

Hæmoglobinuria and Urobilinuria.—

8th. 2 A.M. to 2 P.M. Mixed urines. Red in colour. No deposit.

Chart IX.

Case IV (*vide* also Chart VIII).



Oxyhæmoglobin bands, reduced by Stoke's fluid; returned on shaking. Warmed with NaHO hæmachromogen bands, probably indicating reducing body in urine. A few minute reddish crystals present (? bilirubin).

8th and 9th. 10 P.M. 8th and throughout 9th, urine contained no hæmoglobin.

All gave marked acid urobilin band.
All contained albumin.
Bile pigment absent in all.
10th. 5 P.M. *Urine* red. Oxyhæmoglobin.
7.30 and 9.30 P.M. Deep brownish-red.
Oxyhæmoglobin bands confluent.

Gmelin's test for bile pigments negative. Also negative applied as follows :—Lime water added to urine. CO_2 passed through precipitate separated by filtration, and dried; test applied to dried precipitate.

11th. 2 and 3 A.M. Deep brownish-red; considerable sediment of urates.
Methæmoglobin.
No bile pigments.
8 A.M. Light, brownish-red. Oxyhæmoglobin much less in amount.
10 A.M. No hæmoglobin. Acid urobilin band.

12th. Urobilin still present, but not marked. No albumin. A nucleo-proteïd reaction marked.

13th. Urobilin absent.

Throughout the case the urine showed no epithelial or coarsely granular casts (absence of kidney changes). A fine brown granular deposit of urates occurred in urine passed during the second attack of hæmoglobinuria.

Vomit.—On the 11th, vomit dark green in colour. Extracted with alcohol gives Gmelin's reaction for bile pigment.

Blood.—Red corpuscles. Normal in appearance.
3 P.M., 9th. 3,430,000 per c.mm.
5 P.M., 10th. Hæmoglobinuria.
10 A.M., 11th. 2,777,000 per c.mm.
10 A.M., 14th. 3,190,000 ,,
Leucocytes considerably diminished throughout
3 P.M., 9th. 2000 per c.mm.
10 A.M., 11th. 2000 per c.mm.
10 A.M., 14th. 7000 ,,
Intra-corpuscular parasites absent. Cultures made from blood on agar remained sterile.

Evidences of a Malaria Attack previous to Admission.—

I. *Pigmented Leucocytes.*—8th, 11.30 P.M., a considerable number of typical pigmented large mononuclear leucocytes were found. These were in subsequent specimens absent, and only isolated grains found in mononuclear elements.

It will be thus seen that no pigmented leucocytes were found during

or after the second attack of hæmoglobinuria, although there was a marked mononuclear increase.

II. *Crescents.*—Single isolated crescents were found after prolonged search on the 9th, 11th, and 12th.

III. *Leucocytic Variation.*—There was a marked increase in the large mononuclear elements on admission, which underwent a gradual diminution. Immediately prior to his second attack of hæmoglobinuria they again suddenly increased in numbers. During the pyrexia accompanying the hæmoglobinuria this was replaced by a polynuclear increase, the mononuclear increase again being marked on the subsidence of the temperature, and diminishing gradually during the next few days (*vide* Chart IV).

Experiments relative to the Isotonic Point of the Blood, and the action of Quinine in Vitro.—

1.

11.7.99.	Salt solutions of the following percentages.					
	0·37.	0·39.	0·41.	0·43.	0·45.	0·47.
Patient's blood.....	h.	h.	h.	H.	H.	No "H."
Normal blood......	h.	h.	h.	H.	H.	No "H."
12.7.99.	0·37.	0·39.	0·41.	0·43.	0·45.	0·47.
Patient's blood	h.	h.	h.	H.	H.	No "H."
Normal blood......	h.	h.	h.	H.	H.	No "H."

2.

	Saturated quinine hydroc. in 1 per cent. salt.	Half dilution.	One-fourth dilution.	One-eighth dilution.
Patient's blood ..	h.	h.	Clumping.	Clumping.
Normal blood ...	h.	h.	—	—

3.*

	A normal serum before taking quinine.	A normal serum after taking 2 grammes quinine.
Patient's blood...	No "h."	No "h."

4.

	Patient's serum.
Normal blood	No "h."
Normal blood after 2·0 grammes quinine..	No "h."

Case V.—Five years' residence in B.C.A. Says he had occasional attacks of fever. Was at Chiromo on the Lower Shire 5.7.99, and remained there until 19.7.99. Was badly bitten by mosquitoes whilst at Chiromo. Returned to Blantyre 27.7.99; rode 20 miles on a bicycle, took 0·6 gramme quinine in the evening; 28.7.99, rode five miles, and took 0·3 gramme quinine; 29.7.99, took 0·6 gramme quinine in morning about 8 A.M.; about 3.30 P.M. passed black water, also at 5.30 P.M.; 9 P.M. was seen in bed; said he felt all right; temp. 100·2° F.

30th. 2.40 A.M. Rigor followed by vomiting and profuse sweating.
9.10 A.M. Rigor followed by vomiting and sweating. Slight icterus noticed.
2 P.M. Admitted into hospital; no further vomiting or complication.
31st. No hæmoglobinuria. Albumin and urobilin present.
1st. Left hospital, though still weak.

Hæmoglobinuria, &c.—
29th. 5 P.M. Methæmoglobin.
8.30 P.M. Methæmoglobin.
11.10 P.M. Methæmoglobin; clearer.
30th. 3.25 A.M. Red turbid urine. Methæmoglobin; not distinct. Some pain on micturition. Urine passed at frequent intervals in average amounts.

* The hæmolytic action of quinine on blood is more evident if a saturated watery solution be used and dilutions made with 1 per cent. salt. In this case the hæmolytic action extends to 4 or 5 dilutions.

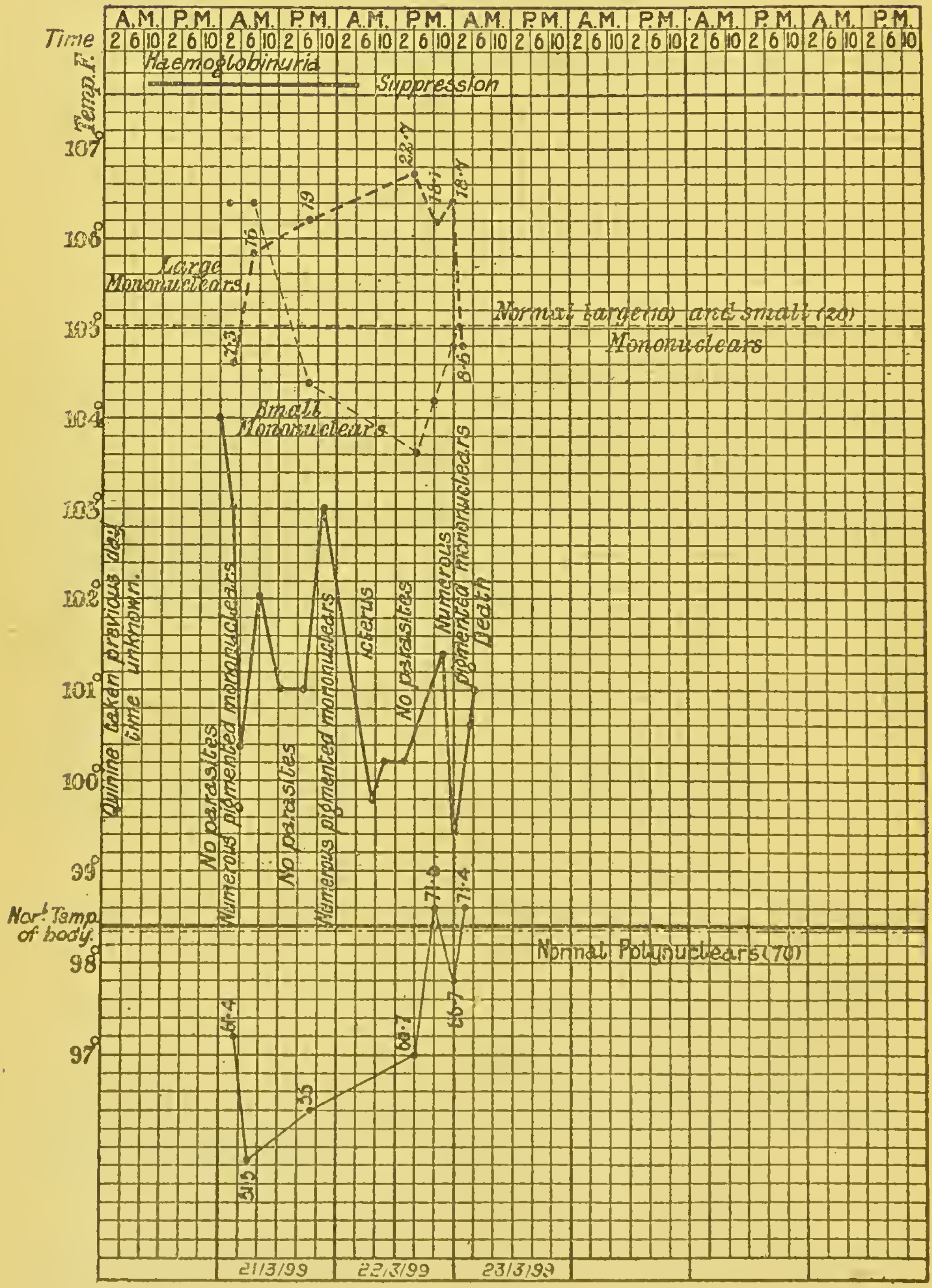
7.30 A.M., 10.15 A.M., 11 A.M., 11.40 A.M., all showing methæmoglobin.

8 P.M. Methæmoglobin.

8.30 P.M. Oxyhæmoglobin.

Chart X.

Case V (*vide* also Chart IX).



31st. 7.30 A.M. No hæmoglobin. Albumin and urobilin present.
1st. 11 A.M. No hæmoglobin; no urobilin; no albumin.

The urine at no time showed any evidence of kidney changes; no casts or kidney epithelium. The early specimens contained abundant urate sediment.

No bile pigment in any of the specimens passed.

No quinine was administered during the course of the disease.

Blood.—Corpuscles normal in appearance and colour.

31st. 5 P.M. Red cells, 3,090,000 per c.mm.; leucocytes, 6000 per c.mm.

No parasites were found in any specimen, though frequent examinations were made.

Evidence of malarial infection.—

1. A typical pigmented mononuclear leucocyte was found in the blood taken on 9 P.M. 30.7.99. They were not found in other specimens.
2. The changes in the relative proportions of the leucocytes was of the same character as those we have already described.

The data will be found on the accompanying chart, where it will be seen that there is a mononuclear increase. (Chart IX.)

In five cases of blackwater we have seen that urobilinuria is a constant phenomenon after the occurrence of hæmoglobinuria. In two cases urobilin was present before the attack; of the others we have no data.

It may then be of significance to determine if possible in what proportion of cases urobilin precedes an attack of hæmoglobinuria, or whether a malarial case with urobilin is in any way more likely to become a case of blackwater than one in which urobilin is absent.

A third case, not reported here, came under our observation.

A patient, in hospital with malaria and urobilinuria. Out of hospital about a fortnight later, he had blackwater fever (after quinine). On his return to hospital again in about a fortnight, malaria (many parasites), urobilinuria.

CHARTS.

The figures in the rings show the sizes of the parasites, *e.g.*, 3 means that the parasite is one-third the diameter of the red cell. The perpendicular columns and the figures at their head shew the number of parasites at a given time, *e.g.*, 1·0 means that an average field contained one parasite and 0·1 that ten average fields contained one parasite.

The leucocytic curve is constructed in the following way. The base line for the large and intermediate mononuclear leucocytes represents a percentage of 10 (a high normal value), while that of the polynuclear represents 70 (a low normal value). Thus in Chart V 31·1 signifies that the mononuclear leucocytes are 21·1 per cent. above normal. The figures represent the average deduced from over

1000 leucocytes counted. It is advisable to have large surfaces of blood evenly distributed. For this purpose by far the best preparations are to be made by distributing the blood on a glass slide by means of the flat end of another slide (it is necessary to ascertain that the slides fit one another, as a slight curvature is often present), or by simply using a needle. Cigarette paper used for this purpose gives extremely bad films.

The large mononuclear value includes also the intermediate cells, while with the polynuclear are included cells of a transitional type.

Chart I.—Exemplifying tertian character of fevers.

Chart II.—Showing continuance of fever, in absence of parasites due to taking of quinine; also the large leucocytic variation.

Chart III.—Showing continuance of fever in absence of parasites and a late development of the leucocytic variation.

Chart IV.—Showing leucocytic variation and its connection with the temperature curve; the mononuclear elements increase with the fall and the polynuclear with the rise of temperature.

Chart V.—A further example; the variation is well marked.

Chart VI.—Showing great mononuclear increase throughout.

Chart VII.—(Case 3.) Blackwater fever. A typical malarial chart with marked leucocytic variation; sudden interruption, coincident with pernicious symptoms; collapse; administration of quinine; disappearance of parasites; hæmoglobinuria; death.

Chart VIII.—(Case 4.) Blackwater fever. Taking of quinine; hæmoglobinuria; absence of parasites; presence of pigmented leucocytes; leucocytic variation; recovery.

Chart IX.—(Case 5.) Blackwater fever. Quinine hæmoglobinuria; absence of parasites; pigmented large mononuclear leucocyte; leucocytic variation; recovery.

Chart X.—(Case 2.) Blackwater fever. Quinine hæmoglobinuria; absence of parasites; pigmented large mononuclear cells; leucocytic variation; death.

"Distribution of Anopheles in Sierra Leone. Parts I and II." By J. W. W. Stephens, M.D. Cantab., and S. R. Christophers, M.B. Vict. Received April 5.

Part I.—*Freetown.*

The Malaria Expedition from the Liverpool School of Tropical Medicine* visited Freetown during the months of August and September. They found two species of anopheles (large and small) in abundance, and in two institutions, where there were at that time many cases of malaria, about 25 per cent. of the anopheles had sporozoites in the salivary glands or zygotes in the median intestine. They also found that anopheles bred exclusively in small pools scattered throughout the town; and in a report to the Governor of Sierra Leone they considered that an extermination of anopheles was possible

* *Editorial*, 'British Medical Journal,' Sept. 9 (p. 675) and 16 (p. 746), 1899.

by destroying the larvæ in these pools. Following the recommendation in this report, the sanitary authorities of Freetown applied tar regularly for a period of some months to these pools, but as soon as the tar applications were discontinued the anopheles reappeared everywhere in their old breeding-places.

Freetown occupies a strip of gently sloping ground between the sea and the base of steep, densely wooded hills which lie behind it. The strip is composed of lava rock (laterite), and though in places a thin covering of earth is present, yet the greater part of the surface of the ground is formed by an outcropping of the solid rock, the untreated surface of which forms many of the streets of Freetown. The rock weathers so as to form a very uneven surface, and small hollows capable of holding water are very numerous. It is in portions of the town built upon the bare rock that the great majority of the puddles described by the expedition existed during August and September. The central portion of the town in which most of the Europeans reside is built upon clayey earth, through which the rock only occasionally protrudes. The roads are here even, and for the most part have at their sides open triangular drains for surface waters, which if well made do not allow pools to form. In this district only an occasional anopheles pool is noted in the map of the expedition.

Both the east and the west portions of Freetown, however, have large areas where the streets are formed by the natural rock, and if drains exist they are ditch-like and flat-bottomed. In these, pools readily form if there is not a constant flow of water. Such an area of about half a square mile in extent exists in the western portion of the town, and contains the majority of the pools described by the expedition. Another area, not so extensive, in the eastern portion of the town almost completes the number. Both districts are among the most densely populated portions of Freetown.

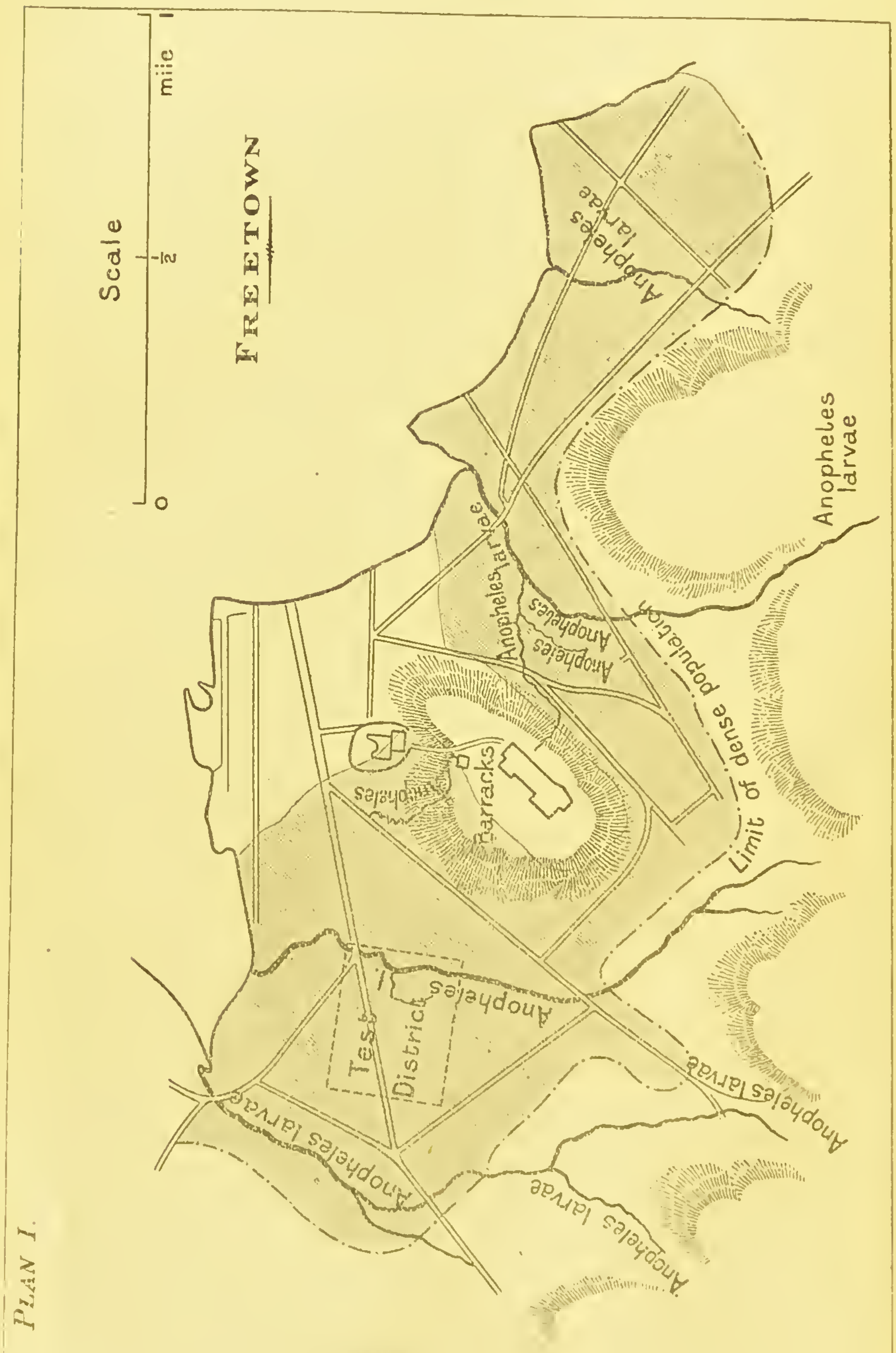
The main rains in Sierra Leone fall during a period lasting from June to October. It is in these months that the puddles exist, as described by the expedition. But from the statement of the sanitary authorities and from our own observation the pools at the end of the rainy season are more numerous than represented. It is in these months that most of the sickness occurs among the Europeans resident in Freetown. From October to the end of March rain is absent, and the soil becomes uniformly parched, and it is a striking feature that during these latter months very few cases of fever occur in Freetown. This holds good both for the Europeans and for the West Indian regiments.

Coincident with this decrease in malaria there occurs a diminution in the numbers of both the breeding-grounds and the adult insects of anopheles.

During December there is a drying up of all the natural waters in

the town. This is hastened during the latter part of January by the Harmattan—a dry wind from the interior. By the end of January

Distribution of Adult Anopheles in the Dry Season.



The shaded area represents the portions of the town where winged anopheles are found with great difficulty, but are sufficiently numerous to restock any freshly formed pool. The clear areas are comparatively free from anopheles.

the rocky areas were, with rare exceptions, free from the pools noted in the map of the expedition. And in the dry season, as we shall see, it

is not in these pools that we have the main source of anopheles in Freetown.

Certain small streams arise from the hills behind Freetown, and flow in their natural channels through the town. Of these, two especially are to be noted—Saunders' and Nicol's brook, situated in the western and eastern portions of the town respectively. These streams in the dry season for varying distances flow over beds of bare irregular rock, forming numerous small rock pools, either wholly or partially detached from the running water. In these, anopheles larvæ were found in abundance. They occur not only in the pools but even in the back eddies and sluggish corners of the stream. We have traced these streams backwards far up into the hills; and here, in the centre of dense bush, wherever a rocky bed allowed of the formation of an isolated pool or back eddy, innumerable larvæ were to be found. A similar condition exists in all the hill streams in the colony of Sierra Leone. Wherever the water can form a small isolated pool, as in a rock hollow, innumerable larvæ existed.

Saunders' brook, which runs through the most thickly populated and most squalid part of Freetown, passes over rock for half a mile of its course, and swarms with anopheles larvæ from December onwards.

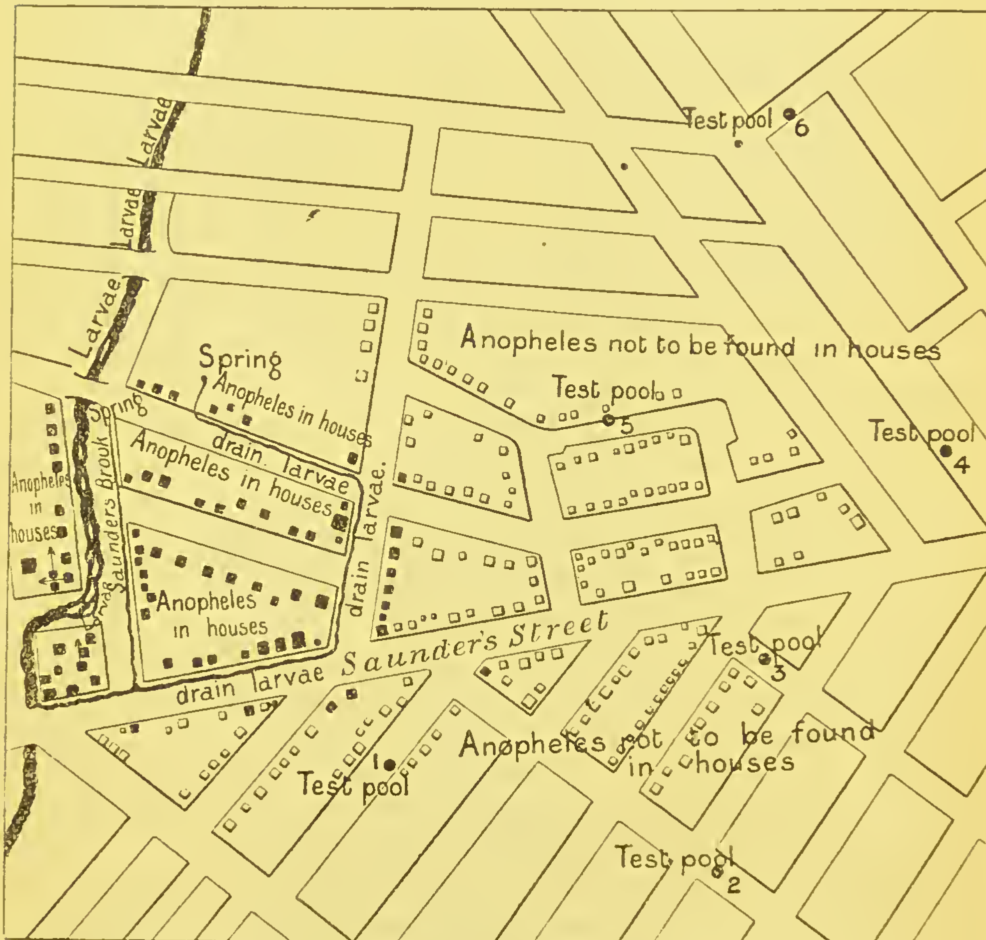
Besides these somewhat considerable bodies of water, anopheles were found to be breeding in several small runnels of water, which were kept from drying either by small springs in the town or by waste water from the military barracks. These small waters are few in number, but usually traverse long and indirect courses before reaching their destination, and are a fruitful source of anopheles from December onwards. At the end of the dry season they are, however, for the most part dry. In no other situations did we find anopheles larvæ in Freetown than in the brooks and small drains.

Considering the rock puddles throughout Freetown alone, we see that they become dried up during three months in the year, and thus cease to serve as breeding-places. This drying up is brought about through natural agencies, which are evidently more effective than any artificial measures which might be resorted to. Nevertheless, anopheles reappear in undiminished numbers in these areas after the onset of the rainy season.

An investigation of the means by which such a restocking of the town by anopheles takes place at the commencement of the rains seemed to us, then, of importance, and a knowledge of this point was necessary before one could form an opinion as to the probable result of measures taken to destroy larvæ in these pools.

A representative district of the town was therefore taken which included a portion of Saunders' brook, a surface drain about 200 yards in length fed by a spring, and a strip of rocky ground which contained numerous pools in the wet season but none in the dry. (See plan.)

In portions of the test district remote from the brook, anopheles were, with rare exceptions, not found by a most careful search in the early morning in very many houses; and among the numerous mosquitoes brought to us by the inmates they were only very rarely present. In the neighbourhood, however, of the brook and drain, anopheles



PLAN II. **TEST DISTRICT.**

Explanation:–

←■ Houses in which anopheles are present in enormous numbers.

■ Houses in which search in early morning reveals a few anopheles.

□ Houses in which anopheles cannot be found.

• Test Pools 1,4,5, are natural rock hollows; 2,3,6, are cement-made hollows

were to be detected in most of the houses. But even here, in well-built, clean houses, it was difficult to obtain them in the early morning, such anopheles as entered at night appearing not to remain. In small dirty and dark houses, however, a variable number were always to be obtained. Here and there in the district bordering upon the stream were certain thatched sheds in which native boys slept. The inmates of these lodging-houses numbered as many as twenty, all

sleeping upon the ground in a space of about 1500 cubic feet. These overcrowded sheds were especially the abode of anopheles. In such places female anopheles were found in large numbers, while in houses immediately adjoining they were difficult to obtain. Males were also to be found, but much less frequently than the females. We would draw especial attention to the fact, of which we shall give further instances, that in native dwellings—and in these overcrowding is often extreme—anopheles are frequently present in enormous numbers. Out of seventy anopheles examined from one of these sheds five contained glands crowded with sporozoites, and one contained two small zygotes. An examination of the blood of sixteen of the inmates did not reveal any crescents. Nor was this exceptional, for in native quarters we have frequently found a percentage of anopheles with sporozoites, though cases of fever could not be discovered. In all cases of anopheles from native quarters examined by us the sporozoites have been greatly in excess of the zygotes, and it is probable the sporozoites remain unchanged for considerable periods in the glands. Nor does feeding apparently exhaust the supply of sporozoites, for the glands of freshly-fed mosquitoes are only in part emptied of secretion, and portions of the glands still contain numerous sporozoites.

We found, then, in the dry season along the course of the streams an unlimited supply of anopheles; and in the houses adjoining, anopheles were found in numbers under the above-described conditions, whilst at a distance from the streams anopheles were rarely to be obtained. The view then seemed possible that in these streams we had the origin of the mosquitoes which reinfest all the pools during each rainy season. But there was another possibility, viz., that mosquitoes remained concealed in grass, shrubs, and trees during the dry season ready to lay their eggs on the first formation of suitable pools. To test this possibility the following experiments were devised :—A series of small artificial pools were made in different parts of the test district. Some of these were small natural hollows in the rock, others were formed with cement. The position of these pools is shown in the plan. They were pools selected as far away as possible from Saunders' brook. These five pools were kept supplied with water from the tap supply of the town. They all without exception after some days contained minute anopheles larvæ. The experiment was repeated with an identical result. In one pool the experiment was performed three times with the same result. It is an interesting point that the occurrence of culex was the exception not the rule in these pools.

Control pools covered with mosquito net remained free from anopheles larvæ.

That both the pools formed in the receptacles made of cement and the twice filled natural rock hollows were infested shows that adult

anopheles themselves are present throughout the dry season, and that the result was not due to the development of ova.

It is very unlikely that ova should be able to withstand the intense heat of the sun upon the rock for so many months. We have found that desiccation on blotting paper for twenty-four and forty-eight hours respectively did not prevent subsequent hatching. Further desiccation, however, did so. It is possible that the natural conditions were more favourable than artificial drying. The earth from twenty-five dried up anopheles pools was therefore collected, and the effect of adding water in shallow trays observed. In no instance did larvæ develop. The experiment then confirms our deduction from the fact that larvæ were found in pools made of cement only.

Although it is almost impossible to find anopheles in houses in the dry season, this experiment proves their continued presence in the district. So that we have here alone a source of anopheles amply sufficient to restock with larvæ innumerable pools during the rains as all of our artificial pools were stocked. In fact, we consider that in a large part of Freetown, especially the outskirts, the conditions are parallel with those which we shall describe in Part II as characteristic of the bush. We can hardly hold that the anopheles were derived from the streams at this season of the year, for the uniformity with which the artificial pools became infected negatives this view.

The fact, then, that at the end of three months in this area, which was free from breeding-grounds, anopheles are still to be found ready to lay their eggs is an important one, and the negative result of the experiments of the sanitary authorities becomes easily explicable, and, indeed, might have been predicted.

If we now summarise the sources of anopheles in Freetown, they are—

1. The streams (larvæ).
2. Certain small drains (larvæ).
3. Rock pools (larvæ), in the rains only.
4. The gardens (mosquitoes).
5. The houses (mosquitoes), especially where overcrowding is present.

Before dealing with the large question of the destruction of anopheles, we will first describe our experiments made with larvicidal substances. We selected as the most practical larvicides paraffin oil and salt. These, as it appears from Celli's and Casagrandi's experiments, are the most efficacious of substances, easily and cheaply obtained. Thus petroleum 0·2 c.c. per 100 sq. cm. was found by them to kill larvæ and nymphæ in four hours; saturated salt in thirty seconds; milk of lime, 5 per cent. in forty-eight hours.

The action of paraffin as a larvicide was tried upon—

(*a*) Rock pools,

(*b*) Small runnels of water.

The larvicidal effect in the pools was very striking, most of the larvæ being killed in fifteen minutes, or less. In many cases, again, besides the larvicidal effect, adult females were found next day killed by the paraffin on the surface of the pool, where they had come to lay their eggs. The final result was, however, the same as that experienced by the Freetown authorities, *i.e.*, immediate return of the insects on the cessation of the application of petroleum.

As a test experiment on small bodies of running water, a surface drain was selected arising in a spring not far removed from Saunders' brook, and, after a course of about 300 yards, flowing into this brook. The spring was free from larvæ, and we have rarely found anopheles larvæ in any spring of pure water. The drain, however, teems with larvæ throughout its whole length. Over this drain kerosine oil was sprinkled by means of a watering-pot. About four gallons sufficed to cover the drain thickly with oil. The larvicidal effect was immediate, and on the following day no living larvæ were seen. Four days later traces of oil were still present in places. Eight days later small larvæ were present along the whole drain. In our experiments with paraffin the oil was intentionally poured on in sufficient quantity to spread readily over the pool, so that no larvæ or nymphæ might escape, but in spite of this, so soon as the paraffin evaporates the pools become infested. We have seen, however, that both in pools and drains, paraffin oil at the time of its application is both a certain and swift destroyer of larvæ and nymphæ. A weekly application of paraffin, then, would effectually prevent the formation of the perfect insect in these situations.

In experiments made, it is true roughly, by throwing a few handfuls of salt into pools containing not more than three or four pints of water, no larvicidal effect was produced in three days. No doubt by making the resulting solution stronger a better result might have been obtained.

If we now turn to the question of the destruction of anopheles, we must bear in mind the conditions we have described above. The problem is a difficult one, but the principle which should underlie all such endeavours is essentially that of drainage. Every endeavour should be directed to the prevention of small collections of standing water.

1. We have in the streams a large extent of water, even at the end of the dry season; in the rains these are rushing torrents.

2. We have in the rock pools a series of small collections of water, spread almost over the whole of Freetown, with the exception of the central portion. During the heavy rains they must be even more numerous, while in the outskirts of the town they become innumerable.

3. About six small drains or runnels of long and devious course, already described.

These latter could easily be reconstructed so that the water would flow in triangular channels, or even pipes, and their removal as sources of anopheles would be very beneficial.

The second source of water could, we think, be dealt with more readily, and with less expenditure than the first.

It would not, we think, be difficult to convert the irregular rocky roads in the outer portions of Freetown into roads of an even surface of earth, such as exist in the central portions of the town; nor to construct stone gutters of triangular section throughout the whole of districts now without any surface drains, or with only badly-made and ill-planned ditches, which advance rather than retard the breeding of anopheles.

The difficulties in the treatment of such varying quantities of water as flow in the streams in the dry and rainy seasons respectively we are unable to estimate; but these streams, as we have pointed out, are the main source of anopheles in the dry season, and effective treatment of such a large source ought on no account to be omitted.

No doubt in the absence of constructive works for improving the surface drainage a thorough application of paraffin oil to the pools at short intervals would form, so long as continued, a check upon anopheles. Such a procedure to be efficient, however, must be very thoroughly prosecuted, and we feel sure could not be carried out without considerable expense. Moreover the expense would be a yearly one, as we have seen that immediately operations cease anopheles become as abundant as ever, nor, in the absence of any radical treatment of the streams, could the result be anything but partial.

We have preferred, then, the radical treatment of the rock pools, viz., that involved in levelling and surface drainage, to attempts at destroying the larvæ, even by such an efficient agent as paraffin, though no doubt paraffin would be very useful as a supplementary agent.

That such levelling and drainage would be effective is rendered highly probable by the condition of the central portion of the town, which only differs from the eastern and western portions in the possession of even road surfaces and triangular drains. Here in the dry season anopheles are not to be discovered in the houses, and test pools, similar to those used in the test district and described above, do not become so readily infected. Also in the rains the malaria expedition has marked not more than two or three anopheles pools in this district. We should endeavour, then, to extend more and more this district of comparative freedom from anopheles.

We have seen further that anopheles are prone to collect in small, dirty, overcrowded houses, and that they remain throughout the dry season, very probably hiding in the daytime among the vegetation, of which there is a considerable amount in Freetown. Such factors

should not be neglected, and the removal or regulation of overcrowded hovels, and the clearing away of rubbish and useless vegetation, must have considerable effect upon the general result.

We must refer finally to a condition which we shall describe in detail in Part II of this report. In a small clearing in the bush, on the Sierra Leone Government Railway, are situated two small wooden houses, and adjoining them small native huts, five in number, occupied by the native servants. The country for a quarter of a mile in every direction consisted of dry bushland. Here at the time of our visit, extending over some weeks, nowhere could we find culex or anopheles larvæ. Yet in these houses anopheles and culex were present, and in the native huts they were present in large numbers. Although in the bush itself anopheles were only rarely to be caught at night, yet in the compound the numbers were very great. We must emphasise again this peculiar fact, that in a district where apparently anopheles may be rare, they aggregate in quantity if dirty native dwellings or villages are contiguous. The danger of this condition to the Europeans inhabiting the wooden houses is a very real one, for all the inmates of the dwellings were continually suffering from fever.

Our object, however, in drawing attention here to the condition of things we shall describe fully in Part II, is the following:—

We believe that there is some intention of constructing a light railway in Freetown, and building European residences on one of the adjacent hills. This on general grounds should be most beneficial, but unless the conditions we have described above are appreciated, we cannot expect that it will have the effect of appreciably reducing the amount of malaria. For here we still have a parallel set of conditions to those we have just described. A house built on the top of a hill surrounded with bush, and with its adjoining native huts, will be no freer from anopheles than a house in Freetown itself. The conditions, in fact, will be identical with those at Kissy Asylum and the Wilberforce Barracks, where infected anopheles were readily found by the Liverpool Malaria Expedition.

If this scheme, then, be carried out, the following points must be adequately considered:—

1. The necessity for extensive clearings around the houses, and the prevention of the formation of pools in the clearing.

2. The necessity for cleanly native quarters, and avoidance of overcrowding.

3. The almost invariable presence of anopheles in mountain streams and rock pools.

We may formulate our conclusions in the following way:—

1. In the dry season, in the absence of pools, anopheles breed freely in streams and drains.

2. Anopheles exist in most parts of the town, excepting the central

area, throughout the dry season, ready to lay their eggs when pools appear.

3. Overcrowded native huts and native quarters generally are usually infested with anopheles, and a source of danger to neighbouring houses.

4. That the only adequate method of treating streams, drains, and rock pools is by surface drainage, and the use of well-made triangular gutters.

5. That the destruction of rank vegetation, the destruction of dirty huts, and the prevention of excessive overcrowding in these will contribute largely towards the general result.

Considering what a scourge malarial fever is, and how definite is its cause, no effort should be spared to rid the town, or at least diminish the number, of anopheles that now abound there. The result can almost certainly be effected, but the means adopted must be commensurate with the magnitude of the task.

Part II.—*The Bush.*

1. Immediately outside Freetown we find hills covered with dense bush. These constitute the greater part of the colony of Sierra Leone proper. Throughout the whole of the district anopheles larvæ were present. In the mountain streams wherever there were suitable pools multitudes of larvæ existed. In tracing these mountain streams occasionally for half a mile or so we have found no larvæ, but then a rocky pool occurred, and here they were again found in numbers. As we shall eventually show, the conclusion is not justifiable that where there are no pools with larvæ there are no mosquitoes. Pools simply form a convenient means of detecting their presence, which otherwise may not be easy.

In Freetown we showed how by constructing artificial pools the presence of mosquitoes, otherwise apparently absent, could be detected. Similarly, on the summit of Sugar-loaf Mountain (about 2000 feet), the presence of a small pool with larvæ revealed the presence of anopheles.

The expedition of the Liverpool School of Tropical Medicine found at Wilberforce Barracks, an institution situated upon the hills at a considerable height above sea level, very numerous anopheles in spite of the fact that no breeding-places were apparent. At Kissy Asylum, also situated on the hills and surrounded by bush, a similar condition of affairs existed, namely, numerous adult anopheles without any apparent source.

We shall show, however, that this is no exceptional but a general condition that in the bush, in the absence of breeding-places, anopheles

exist, and, under conditions which we shall describe, often in enormous numbers.

2. In this portion of the report we shall, however, describe more particularly the distribution of anopheles in the districts of the interior, which to a large extent consist of low bushland intersected by extensive swamps. It is here that the colonist, trader, or missionary is often located, and it is country of this description that is traversed in expeditions, military or otherwise, and it is through this bushland that roads and railways are made; it is here that temporary camps are pitched or clearings made, and under such conditions especially as is well known malaria is contracted. A knowledge of the distribution of anopheles, then, is of the utmost importance.

The observations recorded in the present paper refer to the distribution in the dry season. Considerable differences occur in the rains, and the conditions at that time we shall record later.

One hears surmises as to how malaria can be contracted in districts rarely visited by man. In our experience, such conditions are rarely fulfilled, and we shall show how very probable it is that, in the vast majority of cases where men have been supposed to have contracted malaria in uninhabited swamps, they have in reality become infected in houses, camps, or native villages where fever was pre-existent.

At the time of our stay in Sierra Leone an extension of the Government railway was in progress. This afforded us an opportunity of investigating the conditions under which the operatives contracted malarial fever. During the last four months a number of men have been employed in constructing a bridge across the Ribbie River at Mabang, in the midst of an extensive mangrove swamp. Among them malarial fever, as the accompanying chart shows, is almost constantly present. The universal opinion was expressed that their fever was due to working in the fœtid mud of the mangrove swamp, but we shall show that this is not so, and that almost certainly the malaria has been contracted in their houses, built upon slightly elevated and perfectly dry sites. The men's quarters are at Songo and at Mabang.

At Songo there are six houses (numbered in the chart 1 to 6). Of these, 1, 2, and 3 are short distances apart, 4, 5, and 6 are close together in the same compound, and may, so far as anopheles are concerned, be considered as a single house.

At Mabang there are three houses, situations of which are shown on the accompanying plan. Of these, those numbered 7 and 8 in the table are in the same compound, whilst 9 is half a mile away. The occurrence of malaria among the occupants of these houses is shown in the accompanying table. The table shows the house in which the case occurred, and also the week in which the attacked commenced. The figures 2 or 3 denote the number of attacks in the same house.

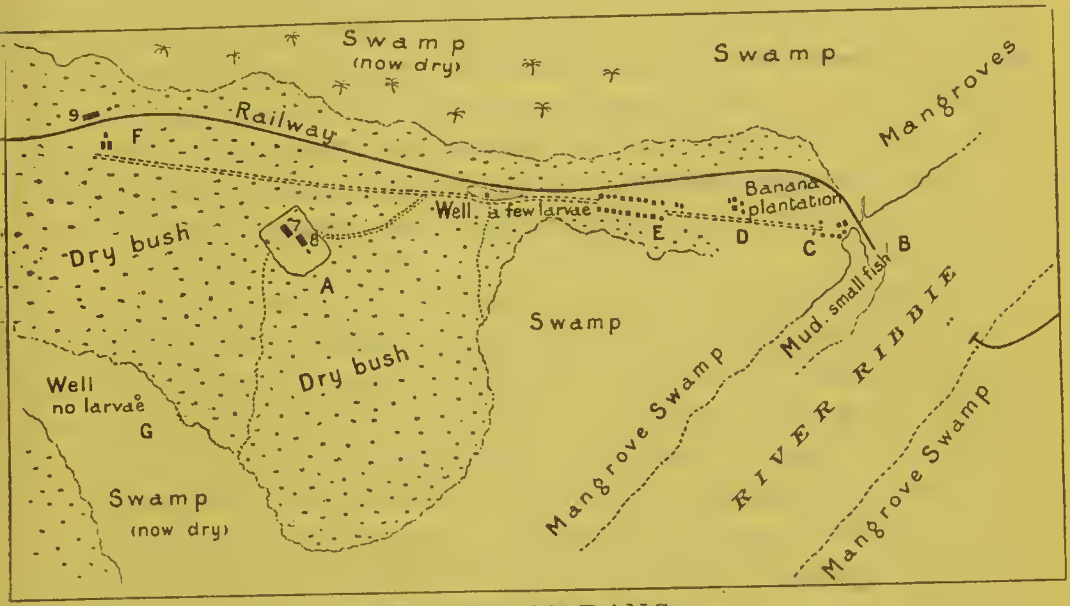
Owing to the absence of records of slight attacks, and from the fact

	July.				August.					September.				October.			
Weeks........	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Songo—																	
House 1	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..
„ 2	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..
„ 3	1	2, B	..	1	2	..	..	..	..	..	..	..	..	..	..	..	..
„ 4, 5, and 6	..	1	3	..	..	1	..	..	..	..	2	1	1	2	2	2	..
Mabang—																	
Houses 7 and 8*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1
„ 9	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..
Camp 1	..	..	1	1	2	1	..	1	..	..	1	..	1	..	..	..	..
„ 2	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1	..	1

	November.					December.				January.				February.	
Weeks........	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Songo—															
House 1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
„ 2	..	..	B	..	..	..	1	..	..	..	..	..	..	..	1
„ 3	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..
„ 4, 5, and 6	..	2	..	1	..	..	.	2	1	..	..	B	..	..	..
Mabang—															
Houses 7 and 8	..	..	..	..	..	..	..	..	2	1	1	3	2	..	1
„ 9	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
Camp 1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
„ 2	2	..	..	..	..	1	1	..	..	..	..	..	..	..	..

B signifies a case of blackwater.
The lines beneath the figures draw attention to periods when the occupants of the houses were suffering constantly from malaria.
* Houses occupied from the second week in October.

that relapses occur, and also from the probability that mosquitoes infected with sporozoites may remain in native quarters for considerable periods before again infecting a European, it is difficult to determine the period intervening between the transmission of malaria from one inmate to another. The table shows, moreover, that it is usual for houses to have a constant succession of cases, lasting six weeks or more, whilst periods of health intervene. Thus in houses 4, 5, 6, in August and September, ten separate attacks of malaria occurred. In house 3 during July seven cases occurred, and in houses 7 and 8 in January most of the inmates had malarial attacks—nine cases in all.



PLAN OF MABANG.

The condition of these houses at such times we were enabled to study in the case of the last of these outbreaks. The plan shows the chief physical features of Mabang. At "B" the men are working surrounded by fœtid mud in the midst of a large swamp. At the time when, however, all the inmates of houses 7 and 8 were suffering from malaria, those working in the same place, but living at house 9, did not so suffer.

At "A," houses 7 and 8 are situated in a small clearing in the bush, upon a slightly elevated site surrounded at distances of from a quarter to a half a mile by large tracts of swampy ground.

The clearing at "A" lies on porous ground, and being slightly elevated is, except in the rains, free from water. At the time of our visit in January and February not only was the compound itself free from any water, but the bush for a quarter of a mile around was without a trace of water or even humidity of the soil.

In spite of this, in the compound mosquitoes were present in abundance. Two species only were found, a culex and an anopheles.

The culex was a species widely distributed in Tropical Africa, and frequenting chiefly swamps and plains of rank grass. On certain nights they could be captured in large numbers, far exceeding those of anopheles caught at the same time. In the daytime, however, the numbers remaining in houses or tents were small, and less than those of anopheles, a fact which is accounted for by the greater readiness of the culex to leave houses in the morning for the bush.

Anopheles were also present in the compound. In the two houses of the Europeans they were present only in small numbers, though such as were found were generally within the mosquito nets.

Within a few yards, however, of each house there were several small hovels built of palm leaves in which the native servants lived. Of these there were five in the compound. In striking contrast to the condition in the larger houses, these contained anopheles in large numbers, and in spite of the numerous facilities afforded the mosquitoes for hiding amongst the leaves of the walls and roof, numbers could always be obtained. At night, anopheles were present in these hovels in multitudes.

We may notice here a statement sometimes made that natives suffer less than Europeans from mosquito bites. This is true only of the irritation following the bites. A native certainly is not only equally but far more frequently bitten than a European. Nuttall, in his *résumé* of the *rôle* played by insects in disease, cites King and Laveran as stating that the immunity of negroes may be due to the fact that they are bitten less frequently either from an odour noxious to mosquitoes or from the possession of thicker skins. That natives do not enjoy an immunity from mosquito bites is very certain; they, on the other hand, attract mosquitoes, and especially anopheles, more readily than Europeans do.

We have already noted in Part I how in overcrowded native huts there is a swarming of anopheles. This is not exceptional; in nearly all native villages anopheles are to be found by search among the thatch of the huts, and if not within, where it is usual to burn fires constantly, at least under the eaves. At C and D, Mabang village, and at E, where the native workmen on the railway have their quarters, and at F, a frontier police station, anopheles were to be found in extraordinary numbers.

That natives powerfully attract anopheles was well shown in the following experiment. In a tent in which a European had been accustomed to sleep, pitched in the compound at "A," only one or two anopheles were usually to be found in the morning. Two natives were then allowed to sleep in the tent, with the result that the first morning nineteen anopheles were captured. The second morning sixty-two anopheles, most of which had fed, were caught. The natives did not complain unduly of mosquitoes. The use of the tent by the natives

was then discontinued, and the anopheles rapidly became fewer in number.

It is well known that the immunity of natives to malaria is by no means absolute, and even severe cases are frequently to be seen, chiefly in children and old people. And, indeed, we have very constantly found a proportion of anopheles from native villages and quarters to contain sporozoites. The proportion is by no means so large, however, as Grassi has found in the Italian malarial districts in the autumn. Very possibly, however, a similar seasonal prevalence of infection is found in the anopheles in Africa. The number of infected specimens in the dry season varied in different localities from one in five to one in twenty or more.

At both A and D a proportion of the anopheles were infected, the numbers at A varying on different occasions from one in five to one in ten.

At Mabang, then, ample cause for the existence of malaria was found in the presence of infected anopheles in the houses where those men suffering from constant malarial attacks lived.

It is evident the native dwellings are fertile sources of anopheles, and the Europeans in every case had such sources within a few yards of their houses.

It is evident from the table of cases given that when once the anopheles in these situations become infected, the infection is kept up for many weeks or months. We may look upon such a house and its accessory hovels as one infected with malaria, or as a "fever house." Such is the universal condition of European houses, indeed, in the remote stations situated in the African bush. It is the condition under which the coffee planter lives in British Central Africa, and the so-called rest houses and river stations of the various companies reproduce the conditions which we have described, and anopheles were found in all.

It is in such houses that the malarial cachectic is living exposed to frequent or even constant reinfection, and in which every traveller staying the night is liable to infection.

From such fever houses the majority of our cases of blackwater have come, and that such should be the case is strong evidence in favour of the malarial origin of tropical hæmoglobinuria.

It has been noticed that the cutting down of trees has apparently been the cause of outbreaks of malaria, and that in Assam and Borneo it is newly-made clearings which especially give rise to malaria. These observations are borne out by the conditions at Mabang, for although anopheles were to be found in unlimited numbers in all the clearings in which dwellings were situated, yet in the surrounding district anopheles occurred very scantily. There is, then, a marked concentration of anopheles whenever a clearing with human, and especially native, dwellings occurs.

In spite, however, of the occurrence of anopheles at A, C, D, E, and F, yet at neither of these places were any breeding-places discovered. Throughout the whole district shown in the plan, anopheles larvæ were found only in a small puddle by the side of the railway in a pit from which earth was being dug out. This puddle contained only a very few larvæ. Such a source was quite inadequate to keep supplied with anopheles the native quarters at A, C, D, E, and F. Close to the village at C there are extensive areas of mud which at low river are covered with small pools of water. Prolonged search in these, however, failed to demonstrate a single larva. That larvæ were not found in such a situation within a few yards of houses containing the adult anopheles in abundance is interesting. The situation is one that has been usually considered essentially malarial, a creek lined with mangroves and with banks of fœtid mud. The pools are subject, however, to daily disturbance by the ebb and flow of the tidal river water, and small fish abound in them—two factors probably sufficient to explain the absence of larvæ.

The conditions in the compound at "A" were even more striking. In every direction for several hundred yards the ground, which was covered with low bush, was quite dry. Search was made for larvæ in the most minute traces of water, such as collect in the axils of banana and other large leaves, but though at C numerous larvæ of a species of culex were found in such situations, those of anopheles were never encountered.

At "A" then, although anopheles abound, yet for some months there could have been no local breeding-ground; the same holds good for C, D, E, and F, except that, unlike "A," here there are swamps in much closer proximity.

It is an important question to what extent swamps are breeding-grounds of anopheles. Search in an extensive swamp for larvæ is difficult, and that larvæ are not found cannot, we think, be considered good evidence against their existence in limited numbers.

We have frequently captured adult anopheles in swamps remote from human habitation, though in such situations they do not seem to occur in such numbers as in clearings and native villages. Thus, in the small dry swamp at "G" anopheles constantly occurred, though in small numbers. We have also captured adult anopheles several miles from any hut. At both Songo and Mabang, however, we have been able to detect anopheles larvæ in swamps. In the main swamp water we have never succeeded in finding them, and the innumerable small fish present in the swamps would probably prevent their being present in any number. They were, however, occasionally observed in small isolated pools on the mud, and they are still more common in small pools at the edges of swamps. But it is a noteworthy fact that the larvæ of anopheles do not occur in swamp pools in such numbers

as in the streams and rock pools among the hills of Sierra Leone. These rock pools would appear to be the most suitable conditions for the breeding of anopheles.

While at Mabang we examined culex which had fed on human blood, and were caught in the native huts at the same time as anopheles. These likewise contained sporozoites in their salivary glands in the proportion of about one in ten. They were found also in unfed culex caught in the bush, and several infected ones were found in the swamp "G," though here the number of sporozoites was always small.

Sporozoites were also found in two out of four specimens of a large species of anopheles found rarely in the bush, and not met with in the native huts. Two questions therefore arise—

1. What is the nature of the sporozoites in culex?
2. What is the nature of the sporozoites in anopheles not found in human dwellings?

The sporozoites of culex differed morphologically from those found in the anopheles in the huts, and their arrangement in the salivary glands was different. In the anopheles the sporozoites were present in large numbers. They were in the form of slightly bent sickle-shaped bodies. Those extended by pressure from the glands floated free in the saline solution, and did not remain in the globules of secretion squeezed out of the gland. Stained with hæmatin they showed a very definite outline and a central collection of chromatin arranged in the form of a ring. The sporozoites in the glands of the culex were usually present in fewer numbers in the glands. They were more slender, and more twisted and irregular in outline. When extruded from the gland they for the most part remained included in the mass of secretion, and were less easily seen than the sporozoites in anopheles.

On staining with hæmatin they showed a uniformly staining substance, but no chromatin. They appear therefore to differ from human sporozoites. The possibility of their being proteosoma sporozoites was then considered. Birds of the district were examined, and though halteridium was present in nearly 50 per cent., proteosoma was not encountered. The birds examined included merops, turdus, fringilla, columba, turtur, francolinus, perdrix, psittacus, agapornis, alcedo, laniarius, falco, rallus, grus, musophaga, rhamphastus.

Specimens of the culex were fed upon birds strongly infected with halteridium, but no zygotes were found in six days after feeding. It seems possible these may be the sporozoites of halteridium. We have at present been unable to settle the question, as the supply of this culex suddenly and unexpectedly ceased. Nor at present can we offer any opinion as to the nature of the sporozoites in the large species of

anopheles. Only four of this variety were found by us. It is improbable that they are derived from parasites in monkeys or bats, as the former did not occur in the immediate neighbourhood, and bats, which we were unable to capture, though present, were apparently very few in number.

The sporozoites did not seem to differ essentially from those found in the ordinary anopheles in the huts, but it is certainly difficult on the view that they are human to account for their existence in anopheles at a distance from habitations and in a species not frequenting houses. We are reluctantly compelled to leave these questions unsettled till the onset of the rainy season, when the supply will no doubt be sufficient.

We may thus sum up our conclusions :—

1. Anopheles infest European houses with their adjoining native quarters in the bush.

2. In such houses infected anopheles occur for considerable periods of time, and many of them may be regarded as "fever houses."

3. Native huts and native villages especially are infested with anopheles, and a proportion of these are frequently infected.

4. That breeding-grounds are frequently absent at a time when anopheles swarm in the houses.

5. That swamps form one of the breeding-grounds of anopheles, these collecting in myriads where dwellings are close at hand.

Prophylaxis.

1. The source of greatest danger to Europeans living in the bush is, as we have seen, the presence of huts in which native servants sleep. It is obvious that to have within a stone's throw of a European house hovels in which anopheles thrive and swarm is a most dangerous condition.

In any permanent settlement in the bush it is, then, essential that this source of infected anopheles be removed. The native sleeping-quarters should be far from the European dwellings, in an independent clearing, and natives should not be allowed to sleep under the same roof, or in outhouses, as now is frequently done.

We would also call attention to the danger of sleeping in native huts, or of having one's camp close to a native village, two conditions which are frequently put into practice by travellers in remote districts.

2. Personal precautions, now so usually flagrantly neglected, can be systematically carried out.

We have ourselves never been bitten on the legs or ankles after dark from the simple precaution of changing one's light clothes worn in the day. We now put on boots and gaiters, puttees or mosquito boots, and thick trousers or cord breeches.

We also took minute precautions in the adjustment of our mosquito

nets. These should hang *inside* the poles, and should be turned in under the mattress. The shotted net which is allowed to trail on the ground is objectionable, as during the day mosquitoes lurk under the mattress from which they sally forth at night, being now inside the net. If the net be turned in under the mattress this is impossible. The bell net in use in places is especially ineffective.

On no account should any hole exist in the net, as it is extraordinary to see the pertinacity with which a mosquito will endeavour to find an entry, always successfully if a hole exists.

In the nets we inspected at Mabang all these conditions were violated; it is not surprising then that here quite often we caught fed anopheles inside the nets in the morning.

The inside of the net should be carefully searched with a candle before going to sleep.

Following out these precautions minutely we were able to protect ourselves in the thickly infected compound we have described.

On occasions, however, one is bitten through the net. This is a frequent manner in which men are bitten, consequently we think an important improvement in mosquito nets would consist in a piece of stout cloth or canvas let in at a suitable level so as to protect the limbs during sleep if, as is frequently the case, they come to rest accidentally against the net.

We may refer here to the conditions which we observed in the house boats and river steamers on the Zambesi. It is very usual for new-comers to contract fever on the way up river and so shortly after reaching Blantyre to have a severe attack of malaria. Infection no doubt occurs in the boats or riverside stations. The nets provided not only usually contain holes, but from their small size, necessitated by the cabin, it is impossible that one should fail to be freely bitten through one's limbs and body coming in contact with the net. By putting up each night a full-sized net on the deck of the steamer we escaped being bitten whilst traversing the river.

Everybody ought to possess a large rectangular mosquito net of their own, which they should never on any pretext travel without. In this way one may with care pass through districts rich in mosquitoes and rarely be subjected to their bites.

3. In the next report we shall deal with measures for the destruction of adult anopheles and with the use of repellent bodies, &c.; but in the circumstances described by us we assign to the strictest personal precautions the position of first importance.

Addendum.

a. Description of anopheles found at Mabang in both huts and in remote swamps:—

Total length, 7 mm.

Palpæ, as long as proboscis. Distal end of ultimate segment, white. Junction of ultimate and penultimate also of penultimate and antepenultimate, white. Thorax and abdomen, dark brown.

Legs brown, evenly coloured, except slightly lighter bands at joints and terminal segment.

Wings with four linear dark brown spots on anterior margin.

Smaller specimens were encountered 5 mm. in length; these possessed identical markings with the larger species.

b. Description of culex found at Mabang with sporozoites:—

Total length, 7½ mm.

Palpæ much shorter than proboscis; uniformly light brown, with extreme tip lighter in colour.

Proboscis light brown, with a band, 1 mm. wide, of dark brown near tip.

Thorax and abdomen hairy, yellowish-brown with lighter spots at side of abdominal segments.

Legs, femur, and titræ of all legs mottled light and dark brown. Tarsi markedly banded light and dark brown.

Wings hairy and dull, light brown; no spots.

A Case of Blackwater Fever (Case VIII), with Observations on the History of such Cases.

F., an engineer on the Sierra Leone Government Railway at Songo Town. Has been in Africa eight years.

His record of recent malarial attacks, kept by the medical officer of the railway, is the following:—

13—18.6.99; 19—22.6.99; 7—10.7.99; 2—5.10.99; 22—25.12.99; 19.1.00, blackwater.

19.1.00. Feeling unwell.

20.1.00. Took phenacetin and quinine, 1 gramme between 12 noon and 1 P.M. Between 4 P.M. and 5 P.M. passed blackwater.

21.1.00. Admitted into hospital in Freetown about midday.

Condition.—Much jaundice, pain in region of gall bladder. Temperature on admission, 102·6°; it then fell to normal gradually, and rose again to 103° before death, on the 23rd.

Patient much troubled by flatulence, thirst, and vomiting. Stupor gradually came on, and patient died 7 P.M., 23rd.

Urine.—Spectroscopically methæmoglobin and much general absorption. Much sediment, consisting of spherical granules of varying size, from that of a red corpuscle to half or less. Sediment stained yellow, identical in appearance with that described in Case I, and resembling in nature granular tube casts, indicating destructive kidney changes.

On the 23rd a few ounces only passed of the same character.

On the 22nd and 23rd the action of the urine was tried upon—

1. Normal blood,
2. The patient's blood.

The observations were made on the stage of the hæmocytometer, and corpuscles counted at intervals of an hour. In neither case was any hæmolysis apparent.

Blood.—Examinations were made on the 21st, 22nd, and 23rd. No parasites were found. A careful examination of the leucocytes was made. The leucocytic variation that we have described in previous cases was not present. We have already alluded to the fact that we have observed its absence in ordinary malaria. The leucocytic values were—

21.1.00.	Large mononuclear	8	per cent.	500 counted.
	Small "	8	"	"
	Polynuclear	84	"	"
22.1.00.	Large mononuclear	11	"	"
	Small "	4	"	"
	Polynuclear	84	"	"
23.1.00.	Large mononuclear	12	"	"
	Small "	7	"	"
	Polynuclear	80	"	"

So that in spite of the large polynuclear excess, the large mononuclear value is as high or even somewhat higher than that of the lymphocytes. A parallel condition occurred in Case II, where, coincident with fatal symptoms setting in, there was a sudden inroad of polynuclears; but still with the large mononuclears in excess of the small mononuclears.

Pigment was looked for, and one typical large mononuclear pigmented leucocyte with pigment clumps was found on the 21st. On the 22nd it was thought that in many leucocytes, mononuclear and polynuclear, extremely fine granules of pigment could be seen. The extremely fine character of the pigment here, and the almost total absence of clumps, is interesting when we compare this condition with that found in the spleen post-mortem.

Tonicity of the Blood.—Observations were made on the 22nd, and we may here recall the fact that there was still hæmoglobinuria on the 23rd, though on both the 22nd and 23rd no hæmoglobinæmia was to be detected by the spectroscope.

A series of salt solutions with a difference of 0·01 gramme per cent. between each member of the series was used. A loopful of blood was added to each of these tubes, containing ½ c.c. of each strength. The corpuscles were allowed to settle, and the result was then recorded—

	Salt solution 1.	Salt solution 2.	Salt solution 3.	Salt solution 4.	Salt solution 5.
Patient	No H	No H	No H	No H	No H
Control 1	No H	No H	*h*	*h*	H
Control 2	*h*	*h*	H	H	H

Note.—H means hæmolysis, *h* = slight hæmolysis.

It is thus seen that there is a striking difference in the tonicity of the blood of this patient and that of control, (1) whose blood may be considered normal, never having suffered from malaria and control; (2) who had suffered from severe attacks of malaria six months previously.

The remaining corpuscles of the patient, then, have an increased resistance. This would appear to be brought about by the destruction of the low-resistance groups of corpuscles, leaving only those of higher resistance. The clinical importance of the observation lies in the possibility of determining whether a patient has previous to his attack a number of corpuscles of high tonicity, *i.e.*, low resistance. We append at the end of this report a few observations made on subjects suffering more or less constantly from malaria, in whom a distinctly raised tonicity could be shown to exist.

It is probable that such a condition is one favourable to the action of a hæmolytic agent. If this view be correct, two factors will determine the immediate recurrence of relapses:

(1) The hæmolytic agent may be sufficiently strong to dissolve still more of the residue of cells of low tonicity.

(2) On the character of the regenerated cells. If the tonicity of the now increased total still remains low, the condition will be unfavourable to further hæmolysis; if, on the contrary, the tonicity is raised, or comes back to normal even, then a recurrence is more probable.

Blood Serum.

22.1.00. Serum markedly yellow in colour. The colouring matter was in such quantity that two small loops of blood coloured 1 c.c. of saline distinctly.

23.1.00. The serum was allowed to separate from the clot in a pipette. Deep yellow in colour. Neither in this or the preceding specimen was there any hæmoglobin in the serum. There were no urobilin bands, but only general absorption of the blue end of the spectrum. The colouring matter was probably bilirubin; but we were unable at the time to apply further tests

The serum separated from the clot had no hæmolytic action on normal blood cells. Nor did the serum become tinged on being left in contact with the patient's blood cells.

In Case III we have already noticed this deep yellow serum and the absence of hæmoglobin in the serum at the time of examination.

Post-mortem. 13½ *hours after death.*

Marked yellow colour of conjunctivæ and skin. Subcutaneous tissues, omentum, and peritoneum deeply stained.

Liver.—Enlarged. 72 ozs. Soft and flabby. Surface shows dark brown mottling. On section, brownish-yellow.

Spleen.—Much enlarged. 26 oz. Soft and diffluent.

Kidney.—Capsule slightly adherent in parts. On section yellowish staining evident. Cortic has areas of congestion.

Brain.—Slight œdœma over convolutions. No pigmentation apparent.

Bone Marrow.—Red marrow of sternum can be squeezed out in large amount as a thick substance like anchovy sauce.

Bile.—The gall bladder contained a quantity of very thick, almost solid black tarry bile.

Pancreas.—Normal in appearance.

Smear preparations and sections were made of spleen, liver, kidney, brain, and bone marrow.

Spleen.—A large amount of melanin was present, chiefly in large macrophages and in mononuclear elements, but also to a less extent in the cells of the splenic reticulum. The pigment occurred in masses and in typical clumps. Cells containing fine granules were very frequent.

Yellow pigment was present, chiefly in the macrophages. No parasites were found.

Liver.—The liver cells contained large numbers of coarse granules of golden yellow pigment. Many large swollen endothelial cells were present in the capillaries, and contained clumps and isolated grains of melanin. Grains of melanin were also present in many normal endothelium cells.

A certain amount of yellow pigment was also present in the large endothelial cells.

In both the liver and spleen small yellow acicular crystals were present in large numbers. Many of these were present in endothelial cells, and were arranged around the nucleus. They were insoluble in dilute acids. They did not give any Prussian-blue reaction with ferrocyanide of K and hydrochloric acid. They were, however, dissolved on prolonged treatment with xylol.

No parasites were found.

Kidney.—The glomeruli appeared normal. No parasites were to be seen in the blood corpuscles in the glomerular capillaries.

The epithelium of the convoluted tubules was granular, and to a large extent shed into the lumen. The staining reactions of the cells were also impaired.

The straight and collecting tubules were all closely packed with granular material of a yellowish colour. The granules varied from the size of a red corpuscle to one-fifth or less. The granular substance was similar to that present in the urine during life, and to that described in Case I of our previous report. They consisted of altered epithelial cells.

The kidney vessels were engorged. There was no leucocytic infiltration. No parasites were found.

Bone Marrow.—A large amount of both yellow and brown pigment was present. Many of the mononuclear elements contained numerous coarse granules of yellow pigment resembling those in the liver cells. Others contained clumps and fine granules of melanin.

Nucleated blood cells were present. Neither the multinucleated cells nor the cells with branched nuclei contained pigment. No parasites were found.

Brain.—No parasites were found.

Bile.—The bile contained numerous irregular yellow nail-shaped crystals. These were unchanged by strong HNO_3. They did not give the Prussian-blue reaction with ferrocyanide of K and HCl. They were soluble in strong alkali.

This preliminary examination of the organs is sufficient, then, to establish the diagnosis of malaria.

We have, then, found malarial pigment in abundance in all our five post-mortem cases.

History of Blackwater Cases.

We have already alluded to the difficulty of obtaining accurate histories, and have asserted our belief that statements of patients unsubmitted to rigorous cross-examination are valueless. We give two instances of this, together with a summary of the histories of some cases of blackwater that have recently been published :—

A. Trader, Sherboro, Sierra Leone. Had fever during his first six months in the country.

8.1.00. Feeling ill in the afternoon, went to bed. 10 P.M. took quinine, 0·6 gramme. 11.30 P.M. a West African medical man gave him more quinine.

9.1.00. 2 A.M., blackwater.

15.1.00. First seen. No parasites or pigment; urine normal. Invalided to England.

This case is instructive, because the patient when first asked said he had not taken any quinine (this meant, as afterwards appeared, that he did not take 5 grains daily).

The case was subsequently quoted as one where the action of quinine could be excluded, although a careful examination elicited the above facts, and that "he, of course, took quinine when feeling out of sorts."

B. Case VIII. Railway accountant, Songo Town, Sierra Leone. According to the patient's statement he had lately enjoyed good health, but the record kept by the medical officer to the railway showed the exact reverse to be the case. The patient probably meant that he had not been suffering from severe fever with high temperatures (105°), as it is quite common to ignore slight but quite definite attacks of malaria.

As this was the fifth case of blackwater that had occurred among the residents at Songo Town within the space of about four months, we determined to examine the conditions under which the railway officials lived there. These are fully described in Part II of our report on the distribution of anopheles in Sierra Leone. Here it will suffice to say that malarial fever was constantly occurring in the small area; that at the time of our visit anopheles with sporozoites were found in this group of houses, so that the presumption was very great that cases of blackwater arising here had a malarial origin.

In Case VIII of our series, as in the majority of our cases, no parasites were found. Had not the post-mortem given clear evidence of malaria we should during life, had the patient recovered, have classed it doubtfully as a case of malaria; but when we consider the case further in the light of the previous history of the patient, the data would we believe have been sufficient to make it certain that the case was malarial, apart from other evidence.

We think it then of importance that the histories of similar cases should be minutely inquired into, and mere casual statements not be accepted as evidence.

It is instructive, then, to consider what have been the histories of these five cases of blackwater, only the last of which we saw.

The data are incomplete, but knowing that this little colony of five persons lived in the midst of infected anopheles, and that actual records exist of the fevers of some of them, we have little doubt that the blackwater fever was in these cases the last of a series of malarial attacks. The patients had malarial fever on the following dates :—

B. 13th—18th, and the 19th—22nd of June, 1899. 7th—10th July, 1899. 2nd—5th October, 1899. 22nd—25th December, 1899. 19th January, 1900. Blackwater.

	July.				August.					September.				October.			
Weeks........	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Songo—																	
House 1	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..
,, 2	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..
,, 3	1	2, B	..	1	2	..	..	..	..	..	..	..	..	..	..	..	..
,, 4, 5, and 6	..	1	3	..	..	1	..	..	..	..	2	1	1	2	2	2	..
Mabang—																	
House 7 and 8†	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1
,, 9	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..
Camp 1	..	..	1	1	2	1	..	1	..	..	1	..	1	..	..	..	..
,, 2	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1	..	1

	November.					December.				January.				February.			
Weeks........	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Songo—																	
House 1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
,, 2	..	..	B*	..	..	..	1	..	..	..	..	..	..	..	1	..	1
,, 3	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
,, 4, 5, and 6	..	2	..	1	..	..	..	2	1	..	..	B	..	..	..	..	..
Mabang—																	
House 7 and 8	..	..	..	..	..	..	..	..	2	1	1	3	2	..	1	..	..
,, 9	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
Camp 1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
,, 2	2	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..

B signifies a case of blackwater.

* Had previously been on many expeditions, &c., and had suffered from malaria before coming to house 2.

† Houses occupied from second week in October.

C. 24th—30th May, 1899. 6th—10th June, 1899. 27th—30th July, 1899. 6th August, 1899. Blackwater.

D. Previously in India. Only out three weeks. Ill more than half the time. Blackwater.

E. Blackwater on voyage home.

F. Much fever. Blackwater. 24.11.99.

We thus see that in this group of houses the officials are frequently suffering from malarial fever, and they have furnished five cases of blackwater.

A detailed account of the malarial histories of these houses is given in the table, together with three of the cases of blackwater.

We may add two cases that came under our observation in British Central Africa. In the house where Case I of our series died there occurred, about four months after, a very severe case of malaria. Similarly the house in which Case III lived was occupied, on his removal to hospital, by his brother, who ten days after his arrival was admitted into hospital with typical malaria.

Besides the previous history of these cases the subsequent history of the patient not infrequently throws light on the nature of the blackwater process. This is especially valuable where parasites are absent, as has been the case in all our cases with the exception of Case II, where parasites existed in large numbers before the attack of blackwater. We have already shown in Case IV how our diagnosis of malaria, though parasites were absent, was established by a relapse of malaria; in Case V how blackwater occurred in the interval between two malarial attacks. We consequently think that if the histories of these cases were only accurately kept, much evidence might be accumulated. It is only rarely that here in West Africa as in Central Africa a microscopical examination has been made, whereas one might almost say in malarial countries the microscope should replace the stethoscope.

In the absence of microscopical evidence we may yet hope for help by a careful record of the histories of cases. We may illustrate this by a review of Koch's 'Ueber Schwarzwasserfieber' and Ollwig's 'Ein Beitrag zur Behandlung der Malaria mit Methylenblau.'

In Koch's publication seventeen cases are recorded. These may be divided thus:—

1—7. Negative. Including two cases where no pigment was found (post mortem) in sections.

8. Positive. Ring forms, unpigmented.

9. Positive. Double tertian.

10. Positive. Many relapses in Germany. Diagnosis, tertian.

11. Positive. Relapse in Berlin. Diagnosis, double tertian.

12. Positive. Numerous ring parasites.

13. Positive. Relapse nine days after attack of blackwater.
14. Positive. Large pigmented tertian parasites some days before the attack.
15. Positive. Relapse in a fortnight.
16. Positive. Numerous ring-form parasites some days before attack.
17. Positive. Parasites before and after attack.

Thus out of seventeen cases we have evidence of malarial infection in ten. Of these, four were relapses.

More striking still are the six cases recorded by Ollwig, in all of which there was evidence of malaria. Three of these are included in Koch's series, leaving three cases of Ollwig.* A brief note of his cases is appended.

I. 16.7.98. Blackwater in Germany. No parasites.

31.7.98. Relapse of malaria. Parasites, small ring forms. Diagnosis, mal. tropica.

II. "He quite lately observed that his urine became dark and slightly reddish after taking only 0·5 gramme of quinine, which dose he was then using."

13.9.98. Parasites. Diagnosis, tertiana duplex and malaria tropica.

III. Two and a half years in German East Africa; much fever there and on voyage home. In Germany.

June, 1898. Blackwater. No parasites.

30.7.98. Parasites. Diagnosis, mal. tropica.

13.8.98. Parasites. Diagnosis, mal. tropica.

Ollwig's remaining three cases are identical with Cases 10, 11, 17 in Koch's series.

The subsequent history of these cases then clearly shows the existence of the malarial infection, which at the time of the blackwater attack was not evident. If microscopical examinations were constantly made in malaria we should have before and immediately preceding the blackwater attacks evidence, we feel certain, of their malarial origin. The value of the later histories of the patients and of microscopical examinations, Ollwig's cases clearly show.

It may be said that some of these cases are fresh infections, but a consideration of the conditions in British Central Africa and West Africa make it only too evident that blackwater patients have long been suffering from malarial fever which eventually culminates in blackwater.

* Ollwig, "Zeitschrift für Hygiene und Infectionskrankheiten," vol. 31, p. 317.

Tabular Arrangement of Twenty-eight Cases of Blackwater.

Author.	No.	Negative or positive.	Evidence for malarial infection.	Quinine history. Intervals in hours.
Koch	1	No	.. ..	Yes, 3 hrs.
	2	No	.. ..	No history
	3	No	.. ..	Yes, some hours
	4	No	.. ..	Yes, a few hours
	5	No	No pigment in spleen	Yes, one hour
	6	No	No pigment in liver or spleen	Yes, a short time
	7	No	.. ..	Yes, 1½ hrs.
	8	Yes	Ring from parasites unpigmented	Yes, 3 hrs.
	9	Yes	Double tertian parasites	Yes, a few hours
	10	Yes	Many relapses in Germany. Tertian	Yes, soon after
	11	Yes	Relapses in Berlin. Double tertian	Yes
	12	Yes	Numerous ring parasites	No Yes, 8 hrs. Yes, 8 hrs.
	13	Yes	Relapse 9 days later	Yes, some hours on three separate occasions
	14	Yes	Large pigmented tertian parasites some days before attack	Yes, very soon after
	15	Yes	Relapse in a fortnight	Yes, some hours
	16	Yes	Numerous ring parasites some days before attack	No Yes, 3 hrs.
	17	Yes	Parasites before and after attack	Yes, 2½ hrs. Yes, 2 hrs. Yes, 2¾ hrs.
Ollwig	18	Yes	B.W. in Germany. Relapse in a fortnight Parasites, malaria tropica	Yes, some hours
	19	Yes	In Germany. Parasites, malaria tropica, malaria tertiana duplex	Yes
	20	Yes	B.W. in Germany. A fortnight later parasites, malaria tropica	No history
Malaria Commission	21	Yes	No parasites. Mononuclear variation, much pigment during life, also post-mortem	Yes
	22	Yes	Parasites numerous before attack, no parasites after. Much pigment and developing crescents post-mortem	[Yes] ?, 23 hrs.
	23	Yes	No intracorpuscular parasites. Mononuclear variation pigment, a very few crescents, relapse of malaria tropica	Yes { 10 hrs. 4 hrs.
	24	Yes	No parasites. Mononuclear variation, pigment scanty	Yes, 7½ hrs.
	25	Yes	B.W. between two attacks of malaria tropica	Yes
	26	Yes	Much pigment in spleen	No history
	27	Yes	Much pigment in spleen	No history
	28	Yes	No parasites. No mononuclear variation pigment during life, much pigment in spleen, liver, and bone-marrow	Yes, 4 hrs.

Analysis of Twenty-one Post-mortem Examinations of Cases of Blackwater Fever.

Author.	No.	Negative or positive.	Evidence for malarial infection.
Koch	1—2	Negative	No parasites, no pigment.
Thin*	3	Yes	Pigment very scanty in spleen, sporulating parasites in brain.
F. Plehn†	4—16	Yes	In all malarial pigment in organs, but sometimes very little.
Malaria Commission	17—21	Yes	In all malarial pigment in abundance.

In 75 per cent. of these cases and 90 per cent. of the post-mortems, then, there is satisfactory evidence of malarial infection. That a large proportion of cases of blackwater should, however, be described as non-malarial is not surprising. In all our cases, although malaria was undoubtedly present, yet in none of the cases were parasites present during or immediately after the attacks.

This absence of parasites indeed is the most frequent condition in blackwater, and is a strong argument against the special parasite theory. Thus, in Texas fever Koch notices that the number of parasites seen in the blood is proportional to the extent of hæmoglobinuria, the exact reverse of blackwater.

That when parasites are found they are aestivo-autumnal or tertian forms indistinguishable from the ordinary types, is also against the view of a special parasite.

Still another strong argument is the fact that infection so rarely takes place before the patient has been a considerable time in the country, one or two years; whereas malaria in man and Texas fever in cattle affect man and animals respectively independently of the time of residence.

That blackwater should not occur for a considerable time after a patient's arrival is indeed in accordance with the view that it is a condition induced by frequent attacks of malaria, which after a time under certain conditions may give rise to blackwater.

In favour of this view, too, is the fact that in the cases of blackwater on the Sierra Leone railway the patients were living in houses where anopheles were found infected with sporozoites, and that the previous histories were undoubtedly malarial.

Koch recently and F. and A. Plehn previously have confirmed the early observations of Tomaselli that quinine is a cause, and indeed the

* 'Lancet,' 1899.

† Private communication to Malaria Commission.

most frequent cause, of hæmoglobinuria. We have not seen any case in which quinine could be excluded, and in most of our cases the interval between the administration of quinine and the onset of hæmoglobinuria was very constant, *i.e.*, from four to ten hours. We have ourselves had one case in hospital in which quinine appeared definitely to induce a severe attack of hæmoglobinuria. What the conditions are which determine whether quinine or other causes in a malarial patient can induce blackwater remain still to be established.

Observations on the Tonicity of the Blood of Persons suffering periodically from Malarial Attacks.

	1st salt solution.	2nd.	3rd.	4th.	5th
1. Control	trace	H	H	H	H incomplete
2. L. .... 6 months in Africa.	trace	H	H	H	H incomplete
3. M.	*h*	CH	H much	CH	CH
4. H.	*h*	CH	H slight	CH	CH
5. B.	*h*	CH	H much	CH	CH

h = slight hæmolysis, H = considerable, CH = complete.

A second observation was made a few days later on M, with a different control in this case. The result was:—

	Salt 1.	2.	3.	4.	5.	6.	7.
1. Control ..	No H	*h* faint tinge	*h* faint tinge	*h*	H	H incomplete	H incomplete
2. M.	*h* strong tinge	*h* strong tinge	*h* strong tinge	CH	CH nearly	CH rapidly	CH rapidly

The result then agrees very closely with the first observation. It is difficult without making the test a quantitative one, as by using colorimetrical methods, to express exactly differences in words, but to the eye the differences are clearly visible. The blood of M, also of H and B, showed then a raised tonicity, whereas that of L, who had been in West Africa only six months, was equal to that of the control.

It must be noted further that unfortunately different series are not comparable one with the other owing to the fact that on each occasion different salt solutions had to be employed.

ADDENDA.

I.

After this report had been written we had the opportunity of examining a patient convalescent, from blackwater, ten days. His tonicity was again found to be lowered when compared with a normal control, thus :—

	1st strength of salt.	2nd.	3rd.	4th.	5th.
Patient	No H	No H	H	H	H
Control	No H	H	H	CH	CH

The difference in strength between each salt solution was 0·01 gramme per cent. ; in the 3rd, 4th, and 5th dilutions the amount of hæmolysis was in each case less than in the corresponding normal control. (CH = complete hæmolysis.)

As the result then of these few preliminary observations it appears that persons suffering periodically from malaria have a raised tonicity, while in these two cases of blackwater the tonicity was lowered—in the fatal case markedly so, in the convalescent less markedly.

II.

The condition of the blood in the convalescent from blackwater is an interesting one. We have given above the history of the case. The patient was first seen on the sixth day after the attack. An examination of the leucocytes made it evident simply by inspection that there was a mononuclear increase.

A count of 1200 leucocytes gave the following values :—

Large mononuclear	22·7
Small mononuclear	12·6
Polynuclear..................	64·7

and although at first we considered that pigment was absent, yet on a more prolonged examination several leucocytes, chiefly mononuclear, contained fine granules.

We have already alluded to the persistence of this mononuclear variation in malaria after subsidence of all symptoms and disappearance of parasites from the circulation. The following two cases further illustrate this point:—

Case I. 27.2.00. Blood. Numerous parasites. Quinine gr. x were then taken.
28.2.00. Quinine gr. xv.
1.3.00. Quinine gr. xxv.
3.3.00. Blood examined. No parasites. Pigment extremely scanty, one typical large mononuclear leucocyte only being found. Leucocytic count (500).

Large mononuclear	24
Small mononuclear	24
Polynuclear	52

Case II. 24.2.00. Severe attack of malarial fever; then quinine taken daily.
1.3.00. Pigmented leucocytes found, three in number. Leucocytic count (500).

Large mononuclear	29·6
Small mononuclear	18·8
Polynuclear..................	51·6

Accordingly the conditions of the blood of this patient convalescent from blackwater and of the malaria patients exhibit a close parallelism.

"A New Anopheles (*A. paludis*) from Sierra Leone." By F. V. THEOBALD, M.A. Communicated by E. RAY LANKESTER, M.A., F.R.S. Received May 9, 1900.

Anopheles paludis, n.sp.

♀ Head dark brown with a few curved white scales in front, upright white ones in the middle and upright black ones at the sides, a tuft of yellowish hairs projecting forwards; antennæ dark brown to almost black, basal joint dark, the whole covered with a white pubescence, verticils dark brown, the first three or four basal joints with a few white scales; palpi densely covered with black scales with four narrow rings of white scales; proboscis covered with black scales, testaceous at the tip.

Thorax brown with a greyish tomentum longitudinally adorned with darker lines and with scattered yellowish, curved, hair-like scales;

scutellum brown with a purplish tinge, and edged with chestnut-brown bristles; metanotum deep brown; pleuræ dark brown with a few pale reflections.

Abdomen deep steely black, with a few small irregular deep ochraceous marks seen in some lights, covered with deep-brown hairs, which appear black in some lights.

Legs deep ochraceous, with dark-brown scales, the apices of the metatarsus and first tarsal joint of the fore and mid legs with a narrow yellowish apical band; hind legs with the metatarsus very long and thin, the extreme tip of the first tarsal joint and the whole of the three following joints pure white like *A. dubius*, mihi; in the fore and mid legs the last tarsal joints are slightly paler than the rest of the legs, of a somewhat ochraceous tinge in certain lights; ungues dark brown, untoothed.

Wings very much as in *Anopheles sinensis*, Wied., veins clothed with creamy yellow and black scales, the costa dark, broken by two small yellow spots, one near the apex and the other about a third of the length from the apex, the apical spot extending on to the first long vein and the upper fork of the second long vein, the other spot passes into the first long vein only; there is also a yellow spot nearer the base on the same vein, which, however, does not reach the costa; fringe of the wings dark, except where the lower branch of the fifth long vein joins the border, where the cilia form a broad yellow spot.

Length.—5 to 5·5 mm.

Habitat.—Katunga, Sierra Leone.

Date of Appearance.—January.

Observations.—Three specimens of this species received from Mr. S. R. Christophers, only one at all perfect as far as the legs go, but luckily all parts were present on combining the three, so a complete description can be given.

With the hind legs absent this species closely resembles *A. sinensis*, especially in regard to the wings; the white tarsi in the hind legs, however, clearly separate it from that species. The white tarsi make it resemble *A. dubius*, but the wings differ; in this species the fringe has only one pale patch at the end of the lower half of the fifth vein, whereas in *A. dubius*, mihi, there are several small pale patches; there are also only two pale costal spots as in *A. sinensis*.

Mr. S. R. Christophers, who sends this species, says in his letter that "it occurs very infrequently, and we have been unable to obtain any males. It occurs widely distributed, but rarely, in the Sierra Leone swamps. This species has been shown on two occasions to contain sporozoites in the salivary glands, though caught about a quarter of a mile from any human habitation."

It is undoubtedly a distinct species, coming near *A. dubius*.

ROYAL SOCIETY.

FURTHER REPORTS TO THE MALARIA COMMITTEE, 1900.

BY

S. R. CHRISTOPHERS, M.B., AND J. W. W. STEPHENS, M.D.

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1900.

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AUGUST 15, 1900.

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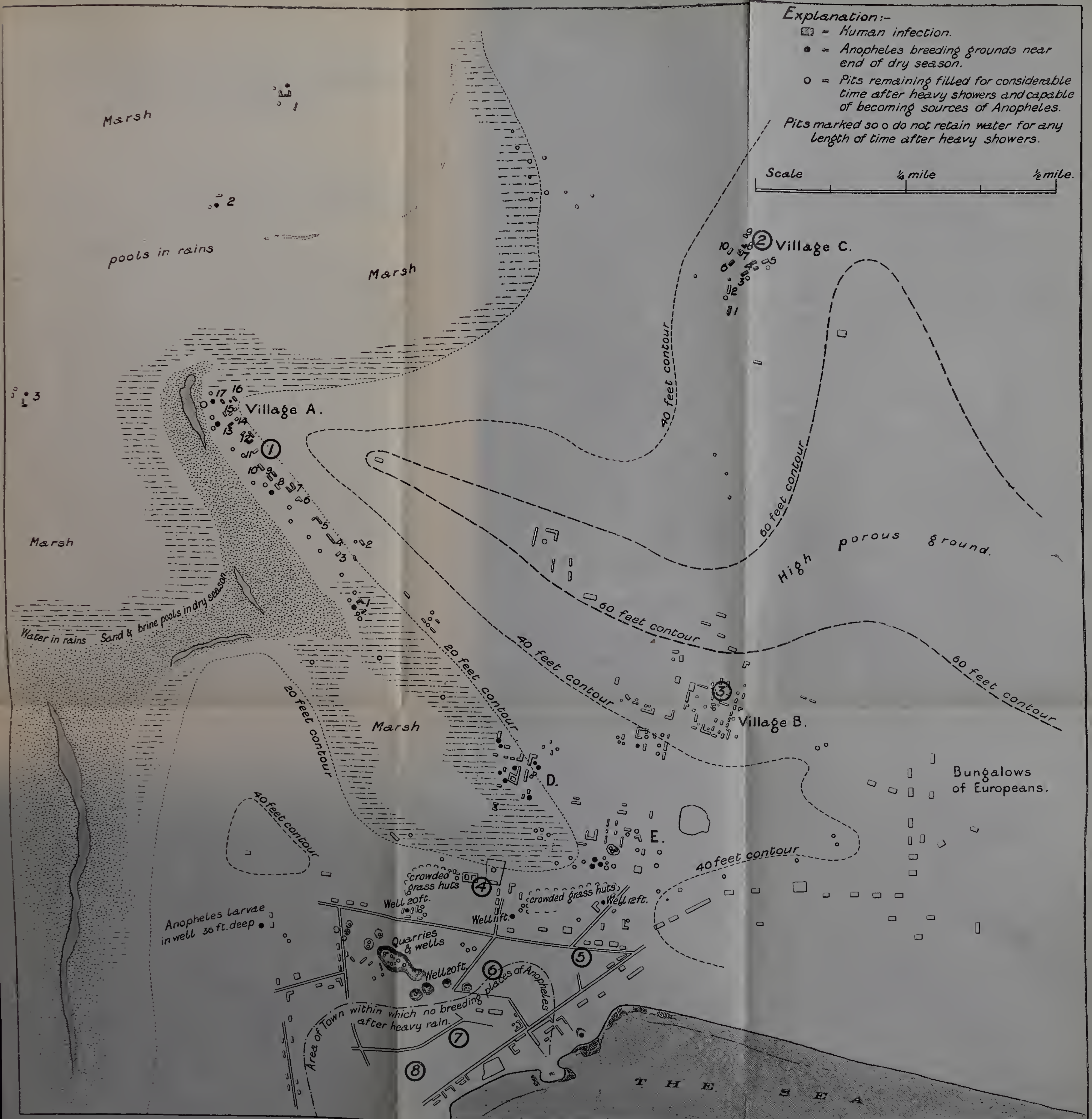


Sketch Map of Town of Accra, Gold Coast, and Neighbourhood, to illustrate the part played by Native Dwellings in the Dissemination of Malaria.

FURTHER REPORTS TO THE MALARIA COMMITTEE OF THE ROYAL SOCIETY.

"The Native as the Prime Agent in the Malarial Infection of Europeans." A Report to the Malaria Committee of the Royal Society. By S. R. CHRISTOPHERS, M.B., and J. W. W. STEPHENS, M.D. Received June 8, 1900.

I. *Breeding Places in their relation to Native Dwellings.*

The Formation of Breeding Places.—The breeding places of anopheles are of a somewhat special nature. Thus large bodies of water, or even large pools, rarely contain larvæ; and generally they are not found in pools which are of long standing, in which there is much vegetable matter; nor in pure spring water. Pools which are thick with suspended matter frequently contain many larvæ, and they were frequently to be found in Accra in pools brackish to the taste. One pool in which larvæ were very abundant contained as much as 0·6 per cent. of salt.

An essential condition is shelter. Anopheles larvæ are surface feeders and have a special arrangement by which they feed with the head twisted, so that the dorsal surface is brought to lie ventrally. A still surface is therefore necessary for them to thrive. The food of anopheles larvæ in the majority of specimens examined by us in Accra consisted of a unicellular organism (protococcus ?). This formed the great bulk of the contents of the alimentary canal in larvæ taken from a number of pools of varying appearance. The pools in which anopheles larvæ appear to flourish best have a very faint opalescence, or even a green scum of this organism on the surface.

The occurrence of natural pools suitable to the growth of anopheles depends upon the character of the country. Thus in the hilly parts of Sierra Leone, such natural pools were very common; but in sandy districts they occur very rarely.

Wherever such pools have been found, they have, however, in nearly every case contained anopheles larvæ, quite independently of the proximity of human dwellings. In the country around Accra, however, we were unable to find a single natural breeding place.

Although a district may apparently be free from natural breeding places, yet around human dwellings breeding places are provided. In the building of native huts it is the usual practice to form the walls, or to make a platform, of dried mud. This is generally manipulated in a pit dug close at hand. After the building is completed the pit remains, and so around each native hut there are one or more of these pits. In very dry districts, such as that of Accra, with a rainfall of only 27 inches, pits of considerable size are also excavated for collecting and storing rain water, so that in and around native villages we may have as many as thirty or forty pits of varying depth and capacity. Most of these pits form breeding places of a suitable nature. Thus in Accra district, where natural breeding places are of extreme rarity, artificial ones exist in many hundreds.

The relation of Breeding Places to Ground Water and Lagoons.—As the dry season progresses the majority of the pits become dry and cease to be breeding places. The soil and subjacent rock (sand, gravel, and sandstone) are both extremely permeable to water. The drying of these pits depends, therefore, more on the general subsidence of ground water than upon actual evaporation of the water in the pit itself. The result is that breeding places exist only where the ground water is sufficiently near the surface to be reached by the deeper excavations (6 to 10 feet). In the beginning of April only those pits marked as blue spots on the accompanying map contained water. Towards the end of April a further reduction had taken place; so that in the whole district the number of pools available for anopheles did not exceed a dozen.

From the permeability of the soil and rock and the absence of rain, the ground water level was very uniform throughout the district and approximated indeed to the sea level. In wells in Accra water is reached at depths corresponding with the height of the ground above sea level. On the higher parts of the district (40 feet to 60 feet or more above sea level) in the dry season the ground water is not reached in the numerous pits existing everywhere, and in consequence large areas there are free from breeding places during the continuance of this season.

Around the borders of the lagoons, however, which are a feature of the coast, the conditions are different. Here the ground water is reached within a few feet, and even in the driest season is found in some of the numerous pits dug along the margin by the natives; and in such situations many breeding grounds accordingly occur. The number of pits is usually large in such situations, on account of the large number of villages and dwellings the sites of which have been determined by the possibility of obtaining water in the dry season.

The indirect effect of even salt lagoons and low-lying salt marshes is seen in the case of an arm of lagoon which passes in behind Accra.

The accompanying map shows that its margins are thickly populated, and abound with anopheles breeding grounds. Well on in the dry season the breeding places shown around this marsh are, with the exception of the deep wells in Accra discussed later, the only ones in the district.

Similarly, on the shores of a lagoon at Christianborg there are crowded native dwellings, and shallow pits and wells where anopheles breed plentifully.

We shall show later that anopheles easily fly considerable distances (a quarter of a mile or more), and that a considerable proportion of those from native quarters are infected. In the occurrence of native dwellings and the existence of these pits lies probably the explanation of the generally received belief that lagoons are unhealthy.

The Effect of Rain.—At the end of an exceptionally dry season pools of water had been so reduced in number as to be found only on the lagoon margin. Two heavy rainstorms then fell in close succession, and the result was a filling of pools throughout the entire district. Only a certain number of these newly-formed pools retained water for more than twenty-four to forty-eight hours, so that comparatively few permanent pools were formed. The limited extent to which permanent pools were formed (*i.e.*, those lasting four days or longer) is shown by the heavier circles on the map.

These were more numerous in the low-lying portions than on the higher lands. This is well illustrated in passing from village B (*vide* map) downwards, to the groups of houses D and E. In village B one pool only was in existence on the fifth day. After passing the 40-feet contour line, most of the deeper pits contained water. In groups D and E, 20 feet lower, not only the pits but even superficial hollows a few inches only in depth contained water. A fortnight later the majority of these pits contained anopheles larvæ.

The Nature of the Breeding Places in Accra Town.—The greater portion of Accra town is in the dry season free from surface water. There are, however, a certain number of deep wells, varying from 15 to 35 feet in depth, scattered through a considerable portion of Accra. Many of these are kept covered and constantly in use; others are not used, or only occasionally, and are not covered. A considerable number of these latter were found by us to contain anopheles larvæ in large numbers, and no doubt many more, to which we were unable to gain access, contained larvæ.

The depth of the water from the mouth of the well did not seem to influence the breeding of anopheles, as one of the deepest wells in the town (35 feet) contained larvæ.

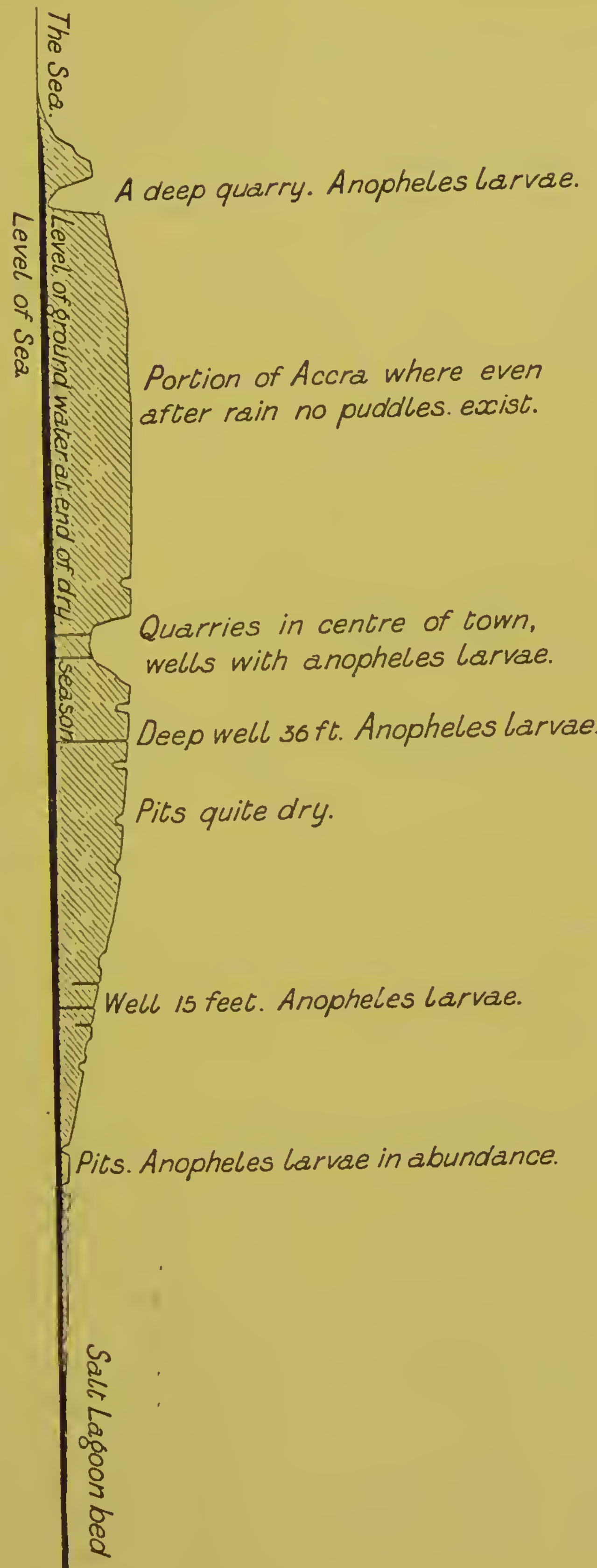
On descending these wells one frequently disturbed mosquitoes which may possibly have been using the well as a resort during the day.

Besides the wells which contained water, there were many dry wells and deep pits, which with the higher level of ground water occasioned by two heavy showers of rain contained water, and were now the breeding places of anopheles. Other pits of lesser depth were also present in numbers capable, with a still higher ground water level, of becoming sources of anopheles. There is, however, one portion of Accra where neither wells nor pits exist, which after heavy rain contained no surface pools. This portion lies in the centre of Accra (see Section).

II. *Anopheles in Native Dwellings.*

In the Presence of Local Breeding Places.—This condition we have already exemplified in Freetown, where in native dwellings, especially overcrowded ones, near the streams which teemed with larvæ, anopheles were caught in large numbers; whereas, on the contrary, in dwellings only a short distance (100—200 yards) away, they were very scanty. In Freetown we found that during the dry season the streams were the main sources of anopheles. In Accra the conditions are very different. Accra, with its scanty rainfall (27 inches) and sandy soil, may be considered the antithesis of Freetown. The native quarter of Jamestown is entirely dry, the soil is porous, and shallow pools do not exist in the town itself. We have still, however, a few deep wells in which anopheles larvæ were numerous, and on the outskirts larvæ were present even in April in a few shallow pools, which in the following week were dry. In Accra, though anopheles in the dry season of the year may be considered rare, or in some quarters possibly even absent, yet it may be noted that everywhere culex (several species) occurs in myriads, derived from tubs used by the natives for storing water. In these, culex larvæ were always present in astonishing quantity. A good example of a collection of native dwellings with breeding places occurs in a village close to Accra (village A, *vide* map); this village, extending along the margin of the salt lagoon, consists of some twenty huts, with numerous pigstyes and enclosures for domestic animals, all adjoining one another. The huts are of mud, mostly with grass roofs from which hang foul cobwebs and stalactites of soot. Among these, and among dirty clothing and bedding, anopheles hid themselves. It was therefore only with difficulty, even here, that under such circumstances anopheles were collected. Similar conditions were found in three isolated houses, where breeding places were in each case close at hand, and anopheles abundant.

In the Absence of Breeding Places.—Where breeding places have but recently disappeared, the number of anopheles does not undergo any perceptible diminution for some weeks. Thus, in one of the isolated houses just mentioned (house 1, *vide* map), situated on the dry lagoon



Section through Accra (Jamestown) from north to south.

bed, the sole local breeding place became dry on April 14th, the nearest breeding place being then over half a mile away. Nevertheless, on April 30th, in spite of several collections having been made betweenwhiles from this house, anopheles were still numerous.

After longer periods of time, as shown both in Freetown and Accra, they eventually become rarer, and may even be apparently absent.

The detection of anopheles is not easy, when we consider the actual conditions under which the search is made. It is generally only possible to search a hut when the inmates have arisen from sleep, when the anopheles consequently have been disturbed, and when to avoid daylight they seek all the crevices and hiding places possible. If the room possesses a mud wall, they still may be found resting here gorged with blood; but where the walls and roof alike are formed of grass or palm leaves search, if delayed for any time, is frequently fruitless. Even then, however, they may still be found clinging to the thatch or rafters, or as mere formless lines on the sooty cobwebs which hang above the fireplace. The dawn of day is the most favourable time, and in European residences, where light penetrates everywhere, search later may be quite negative; indeed if anopheles are not found clinging to the outside of the mosquito net in the early morning, it may be safely concluded that they are absent. Once disturbed in this position they immediately fly off, and are not again seen until the next morning. The numbers detected by search also vary much, and a positive search may be followed by a negative, and *vice versâ*. In huts where little or no light penetrates, anopheles are content to remain; they are, however, as already stated, difficult to find here. We have, however, often detected them here while in European houses, a few yards off, they were very rare after daybreak.

The impossibility then of detecting anopheles in many houses where we thought they probably existed, led us to use more delicate means of determining their presence. We have described how in Freetown by constructing artificial pools of cement, and keeping them constantly supplied with water, larvæ appeared in them after some days; so that the freedom of many houses and areas was only apparent.

In the village B (*vide* map), we have an area which had been free from breeding places for some months. Here by cement pools anopheles were detected, whereas experience had taught us that search in such a district might have been fruitless.

Our experiments in Freetown led us to the conclusion that ova did not exist alive in the earth of dried pools. These experiments repeated here have given the same result, but we found that, provided that there were moisture still in the cracks of the mud, ova taken from these would survive. At the end of the dry season, however, there can be no doubt that living ova do not exist in the site of old pools. When rain first falls, then, we should have a series

of pools ready made over an extensive area, which may be used to detect the presence of anopheles where breeding places had been for long periods absent. However, before recording the distribution of anopheles at the end of the dry season, as shown by the first rains, we should be careful that the pool used as a test is a suitable one.

We find, then, that, as a result of the first rain shower, anopheles larvæ are found near the majority of native dwellings or even isolated huts, however free they may have appeared to be from anopheles. Apart from dwellings no widespread diffusion of anopheles occurred in the Accra district, as the result of the first rains. With the object therefore of detecting anopheles, where previously they might have been supposed to have been absent, pools were examined in various native quarters.

Village A.—Here before the rains, anopheles pools were in existence. They had, however, been reduced to one or two situated at the northern extremity of the village, a quarter of a mile away from the huts of the extreme southern portion. Four days after the rains, larvæ were present again in the pools of the southern portion.

Village B.—Anopheles had previously been detected here by means of a cement pool. None of the pools in this village held water sufficiently long for us to detect larvæ.

Village C.—In this village, although there was no water nearer than a quarter of a mile, and no anopheles had been detected breeding nearer than half a mile, yet in five days after the first tornado, larvæ occurred in the village pools. Search in the huts in this village had previously detected one adult anopheles only.

The Houssa Cantonment.—A still more striking instance of this condition, of which we have now found so many examples—viz., the existence of anopheles independently of local breeding grounds—was furnished by the military cantonment at Accra. This is situated about three miles north-east of Accra, and consists of a collection of Houssa huts and officers' quarters. Before the onset of the rains no surface water existed, either locally or in the surrounding country for a mile or more around. The water supply of the garrison was derived from a deep well about half a mile away, closed in, and consisting of pure clean water. From the porous nature of the soil, small collections of water formed in the drawing of water disappeared at once. We have then in this cantonment a native quarter in the dry season for many months devoid of breeding places, and yet here again, as before stated, we found by search three anopheles, an indication that more existed.

Although after the first rain an extensive shallow sheet of water existed immediately adjacent to the huts, yet the character of the water was not then suitable, and neither culex nor anopheles larvæ were detected in it.

An Isolated Hut.—A small hut, which appeared to be used merely as a temporary shelter on a cassava farm, was found about one mile distant from any other dwellings. Anopheles larvæ occurred here about ten days after the first rain, in a pit previously quite dry. The larvæ in this isolated spot may have been laid by mosquitoes lurking in the hut, or they may have been due to anopheles occurring in the bush, independent of man, as in Sierra Leone. The pit, however, was a well, and they were not found in pools apart from houses elsewhere at this time. These pools, however, were never suitable, so that it is difficult to say how far in Accra anopheles occur, as in Sierra Leone, apart from man.

Accra Town.—It has been previously mentioned that a large portion of Accra was free from any breeding places other than certain deep wells, which nevertheless are few in number and widely separated. There are, however, pits of various depths which in the rains become breeding places of anopheles, and these are both numerous and widespread.

Seven days after the first rainstorm, some of these still contained water. An area was therefore chosen as remote as possible from any breeding place previously existing, and several of these pits were examined. The result was that in the majority anopheles larvæ were detected. In this portion of Accra, then, where breeding places were encountered only at considerable distances, anopheles, as shown by the pool test, were at that time widely distributed. It is in this portion of the town that most of the commercial European residences are situated.

There is, however, a portion of Accra town where a different set of conditions exists. In the very midst of the town is an area, shown on the map by a dot-and-dash line, within which neither wells nor pits exist. After an extensive fire, which burnt down this quarter, well-formed roads with cement gutters were made, and though the dwellings here are very squalid, and many culex are breeding in the domestic pots, yet even after two heavy falls of rain no surface pools existed. It will be seen in the next section that this portion of Accra offers a striking contrast, in one point, to the whole of the rest of Accra.

As a result of these observations, we come to the conclusion that anopheles exist in the neighbourhood of native dwellings in great numbers where breeding grounds are present, and that they generally exist even where for long periods, sometimes for several months, there have been no breeding grounds.

The Flight of Anopheles.—How far this widespread occurrence of anopheles is due to flight from long distances we cannot definitely say. It is certain, however, that under some circumstances anopheles may fly much greater distances than has been supposed. Thus in a

small isolated house which had been occupied by one old man, five or six anopheles were to be caught each morning. These were both male and female, the latter of which usually possessed undeveloped ovaries and imperfectly matured salivary glands, such as only freshly hatched specimens show. These anopheles could be only derived from a breeding place in a village A at the foot of the hill. This would give 300—400 yards as a flight frequently undertaken.

Also along the narrow wind-swept ridge between the salt lagoon at Christianborg and the sea, numerous wells have been excavated to a depth of 10 to 12 feet. Many of these contain numerous anopheles larvæ, which occur also in the wells farthest removed from Christianborg. These are about 600 yards distant from any dwelling.

If the anopheles breeding here are not subsisting apart from man, they must fly backwards and forwards over a distance approaching half a mile. There are many reasons, however, for regarding such a distance as unusual. Thus, in our own bungalow at Accra, we did not find anopheles, although native quarters and breeding places existed under half a mile distant.

Whether anopheles can fly such distances or not, we do not think in the majority of cases the supply of a dwelling is kept up by such means, as one knows, in the case of isolated house 1 (map), large numbers of individuals may remain over for weeks. Also it is difficult to believe that in Accra the limited number breeding in the dry season travel far to take their food.

There seems a connection also between the number present in the dry season, and the number of breeding places which have existed in that region in the rains. This is apparently shown in Accra, where the limited area from which potential breeding places are absent shows a well marked reduction in the number of children infected, whilst a similarly dry area, but with potential breeding places, showed no such reduction. In the rains new factors are present, and a spread of anopheles undoubtedly takes place.

III. *Malarial Infection in Native Dwellings.*

The Extent of Infection among Natives.—We have seen that native dwellings may show one of several conditions:

1. They may have breeding places close at hand, and be infested with large numbers of anopheles. The example given of this was village A (map), and the isolated houses on the marsh, 1, 2, 3.

In village A we examined, as far as possible, the blood of every child under 12. Certain of the huts did not contain children, and in a few cases we were unable to obtain specimens. The houses numbered 1 to 17 are shown on the map, those in which infected children were found being indicated by diagonal lines. No house with children that

was examined was without infection, the uncoloured houses being in every case either those without children or those not examined. Table I shows the number of cases which were found by a single examination of each child's blood.

Table I.—Table to show the Extent of Infection in the Children of a Village where Local Breeding Places are present. Village A.

House.		Ring forms.	Pigmented leucocytes.	Crescents.	Total infections.	Total number examined.
1	..	..	2	1	2	2
2	..	1	1	..	2	4
3	Not examined.					
4	..	1	..	..	1	4
5	..	..	..	1	1	2
6	Not examined.					
7	..	1	3	..	4	7
8	Not examined.					
9	..	..	1	1	2	4
10	..	..	1	..	..	1
11	Not examined.					
12	..	..	..	3	3	4
13	..	2	1	1	3	3
14	No children.					
15	No children.					
16	..	2	..	1	3	4
17	..	..	1	..	1	1
1	Isolated house.. ..	1	..	..	1	2
2	No children.					
3	Isolated house.. ..	..	..	2	2	3
	Total	18		10	25	41

This condition of general infection was also present in the isolated houses on the marsh, viz., in houses 2 and 3, the only ones containing children. It will be seen that two or more infected children may be present in each hut, while in house 7 four out of seven were infected.

Out of a total of 40 children 25 were infected. Of these 10 had crescents (gametocytes), whilst 18 had either ring forms or crowded pigment cells, indicating a present or recent attack. Seeing that one blood examination only was made of each child, it is certain that the children were suffering from an almost general infection, and were the source from which the infected anopheles, found in every house, derived their infection.

2. We next determined to what extent the infection differed from

the above in native quarters where local breeding places of anopheles were non-existent, where for considerable distances no water was available for breeding, but where nevertheless, as we have shown, a certain number of anopheles are generally present.

Village B, though containing numerous pits, was quite devoid of water in the dry season, and distant 200 yards from the nearest anopheles pool, which was situated in a group of houses at the foot of the hill. We were only able here to obtain a single blood film, but this showed numerous pigmented leucocytes.

Village C.—This was a small isolated village, situated on high sandy soil, with no water nearer than 400 yards, and no recognisable anopheles source nearer than half a mile. An examination of the children showed, however, an amount of infection not appreciably less than that shown in village A, where anopheles were breeding.

Out of ten houses examined six contained infected children. 15 children were examined in all, of these 8 showed crescents, whilst 5 gave evidence of recent infection with ring forms. (Table II.)

Table II.—Table to show the Extent of Infection in the Children of a Village where no Breeding Places are present. Village C.

House.		Ring forms.	Pigmented leucocytes.	Crescents.	Total infected children.	Total children examined.
1	..	..	1	2	2	4
2	No children.					
3	..	..	..	1	1	1
4	..	1	2	3	4	5
5	..	..	1	..	1	1
6	..	..	..	2	2	3
7	One child only ..	..	..	..	..	1
8	..	..	1	..	1	1
9	No children.					
10	No children.					
Total		6		8	11	16

The Military Cantonment.—In the cantonment, as we have previously shown, there exists an example of total absence of possible breeding places over a large circumferential area, and the condition has lasted at least as long as three months in the present year. Under such conditions one might reasonably have supposed that the amount of infection would be slight. On the contrary, we found here an extra-

ordinary degree of infection among the children. Out of 25 children examined at random 17 were infected, of which 6 showed crescents and 15 recent infections with ring forms. What conditions were responsible for such a high degree of infection we are unable to say. Anopheles, though probably present in greater numbers than they appeared to be, yet could not have been abundant. Three species of culex, very numerous in the huts, were examined, but yielded negative results. Inquiries showed that the men and their families had not been away from the cantonment for many months. At least it appears evident from these examples that the amount of infection in native children does not necessarily bear any very definite relation to the actual numbers of anopheles present. (*Vide* Table III.)

The Town of Accra.—In those portions of Accra where occasional breeding places occur, and where a considerable number exist during the rains, we have found an amount of infection not very different from those already mentioned. (4, 5, and 6, Table III.)

The central portion of Accra, to which we have already drawn attention as being without breeding places, even after rain, showed a very marked and striking difference. This was the first area in which the infected children were less than 50 per cent. In the position (8) this was especially marked, 5 out of 24 children only being infected; a number which is really less than it appears, as here for the most part very young children were selected.

Table III.—Table to show the Relation between Anopheles and the Amount of Infection in Native Children.

	Breeding places.	Anopheles.	Ring forms.	Pigmented leucocytes.	Crescents.	Total infections.	Total number examined.	Percentage of total infections.
Village A	Present	Considerable numbers	8	10	10	25	41	61
,, B..........	Absent	Scanty	1	5	8	11	15	73
Cantonment	,,	,, ...	6	13	6	17	25	68
Accra, 4, 5, and 6 ..	Scanty	,, ...	4	9	4	14	20	70
,, 7 and 8.....	Absent	Extremely scanty or absent	0	4	7	10	32	31

The Nature of Infection in Natives.—Although among the children so large an amount of infection was present, yet in the adults parasites

were rarely found. Not only was this the case, but among the children themselves a diminution of infection occurred as the age increased. Young babies were infected in general in greatest proportion, then small children, whilst children of 10 or 12 were less commonly infected. Over 12, infected children were rare. Table IV shows this

Table IV.—Table to show Increasing Immunity with Age of Native Children.

	Babies.	Children up to 8.	Children up to 12.	Children over 12.
	Per cent.	Per cent.	Per cent.	
Village A	90	57	28	very rarely infected.
" B	75	50	..	
Cantonment...	71	75	30	
Accra (7 and 8)	23	20	..	

diminished susceptibility as age increases, though the number of bloods examined is not sufficiently great to make these figures more than approximate. Out of 78 infections no parasite other than the malignant tertian was present, and though some infections were diagnosed from the occurrence of crowded pigmented leucocytes, yet these had the appearance of those encountered in malignant tertian cases.

In all but a few cases the infection was scanty, and apparently did not much inconvenience the child, as none of our specimens was taken from supposed cases of malaria, but from children running about and seemingly healthy.

Of the crescent cases only one or two showed them in any number. There was, however, a very rapid change of these bodies into round and flagellating bodies, and even in rapidly prepared dry films they had generally assumed this form. Intra-corpuscular developmental forms of crescents were also frequently encountered. The most curious condition of infection was that in which a few ring forms were encountered; these were frequently large forms, one-third or more the diameter of the corpuscle. In a few cases considerable "ring infections" were present, and in many others the number of pigmented leucocytes led one to think that a somewhat severe infection had lately taken place. It is unlikely that such a condition should be kept up for months without frequent reinfection, and the comparative immunity of the children in the central portions of Accra is against it.

The immunity of native races may possibly be an acquired one, from repeated infection during childhood; at any rate, there can be no lack of infection in native dwellings.

Infection of Anopheles in Native Dwellings.—Among anopheles caught in native quarters, both in Sierra Leone and Accra, we constantly find a certain proportion infected. Whether caught indiscriminately in towns or villages, or collected from individual houses, the result is the same; each batch, with rare exceptions, contains from 5 to 10 per cent. of infected specimens, a proportion which holds good at any rate for the dry season. What the proportion is during the rains we do not yet know.

In village A (map), in every house in which anopheles were caught they were infected. In the houses marked 1, 2, 3, and situated on the flat, grassy lagoon bed, we had houses exceptionally isolated, yet among anopheles caught here specimens were infected. The presence of infected anopheles in native quarters then appears to be not an occasional, but a constant, phenomenon, dependent undoubtedly upon the human infection in such places.

The Analogy between the Transmission of Malaria to Europeans and that of Ngana.—Bruce has shown that ngana is transmitted to domestic animals by means of the tsetse fly from the buffalo and wild game of a district. The trypanosoma was also found by him.

It has also been long noticed that with destruction of buffalo and wild game in a district, both the tsetse fly and ngana became less frequent.

In the very remarkable general infection of native children with an apparently mild form of malaria, and the close relation of anopheles to native dwellings shown by our investigations, and in the transmission thereby of malaria to Europeans, there is a process resembling that which takes place in ngana. Further, the analogy holds good in the conversion of the mild or innocuous type of the native disease into the virulent form in Europeans. We do, however, find severe forms also in natives. It may at least be pointed out that were a European in the Accra district (and no doubt the condition is a general one) to sleep in any native hut without a properly arranged mosquito net, he would be exposed to certain infection. Even were he to sleep a single night within a hundred yards of any native village, the risk would be very great. One of us derived his primary infection in this way six months after entering a highly malarious region. For the first time, whilst travelling, a night was spent in a native village, and, through an accident, without a net. Here, though present, anopheles were not very troublesome; nevertheless a severe infection resulted nine days later. Two other attacks were also traceable to exposure to bites from anopheles near native villages. Apart from such conditions we have never contracted malaria during a residence of fifteen months in highly malarial districts. We have also on several occasions slept, adequately protected, night after night, at the edge of swamps without any ill effect.

In most regions little frequented by Europeans, it is usual in travelling to utilise each night a hut in a native village. The attack of "fever," which is so usual after such journeys, becomes at once explicable on a knowledge of the conditions in native quarters. The gross carelessness with which mosquito nets are used—and only too frequently they are dispensed with altogether—contributes naturally to this end. (See also pp. 20—22.)

Also we have seen that towns on the West Coast of Africa differ but little in the amount of infection present from the villages, and here the European house is most frequently surrounded on every side by native hovels. In towns then, also, it is highly probable that a large number, if not the majority, of cases of malarial infection are derived, not from pre-existing cases in Europeans, but from native sources.

IV. *On the Segregation of Europeans.*

If we consider now the conditions here depicted, we see that from its peculiarities of scanty rainfall and dry soil, from the fact that in some of the areas described we have breeding places, in others not, that we have isolated huts and isolated villages with and without breeding places, and in the cantonment an isolated community under special conditions already described, we find that Accra presents us with a means of estimating the effect of various factors to which importance may be assigned in the spread of malarial infection.

We have seen that although a hut be isolated and without breeding places in the dry season, yet its inmates are infected, and infected anopheles likewise occur.

The same holds good for isolated villages, the infection presenting no appreciable difference from that of a village where there were still breeding places in the dry season.

The same condition held good for the isolated cantonment, also without breeding places in the dry season. Here, for some reason, the infection was particularly great, and the European officers were undoubtedly exposed to infection.

The same holds good for the greater part of Accra town with the exception already noted.

The conclusion from these data—and we have in Freetown partially expressed this conclusion—is that native quarters wherever existent will most certainly be sources of infection.

In a portion of Accra town, already indicated, a partial exception exists. Here probably there are no breeding places for any long period, even at the height of the rains. Although it has been shown to possess a striking diminution in infected children, yet the protection is not absolute, no doubt because it is surrounded by an infected population.

Hence the first means of obvious protection for Europeans consists in avoiding native quarters with their infected population and infected anopheles.

In Accra we have three districts of Jamestown (Accra town), Victoriaborg, and Christianborg. The first we have already described incidentally; it is composed mainly of the large native quarter, but in portions of this, or closely adjoining it, we find many of the commercial residences. A European dwelling in this quarter is thus living in the midst of dangerous sources of infection, and as it is only too common to find nets improperly used, the residents here are certain sooner or later to suffer from malaria.

In Christianborg, at the east end of Accra, the conditions do not differ materially from those in Jamestown, *i.e.*, we have here in close proximity to the European residences numerous native quarters; so that residence here constitutes exposure to serious risk of infection.

In Victoriaborg we have a different condition. This portion consists of official bungalows which occupy an isolated area, remote from both Accra town and Christianborg, and surrounded by a dry sandy area which even in the rains cannot afford many breeding grounds. It is only on the western side that the hospital and a few adjacent bungalows approach Jamestown. This condition of isolation constitutes an admirable feature, and the risk of primary infection here must necessarily be small. In the location of sites it is of the utmost importance that they should not approach the native quarters, and although bungalow 15 occupied by us was less than half a mile from the nearest large village north-west of Jamestown, yet throughout the dry season we did not detect a single anopheles.

Unfortunately no data exist to show where primary infections occur, nor do we find here any microscopical evidence of the malarial nature of febrile attacks, in some of which, indeed, we have been able by microscopical examination to exclude malaria. We must advocate again the absolute necessity for such microscopical examinations.

Further records should be kept of the houses where all attacks, especially primary ones, occur, so that evidence which is now wanting may be forthcoming as to what districts and houses are chiefly malarial.

It is, however, recognised by European residents that Jamestown and Christianborg are "unhealthy," whereas Victoriaborg is "healthy;" *i.e.*, the amount of malarial fever in the former is great, in the latter small.

Wherever such a condition of isolation has been secured, it is imperative also that all local breeding places be done away with; for if a case of malaria be imported into this district the fact that sources of anopheles are present renders a certain amount of infection from this case again possible. In Victoriaborg the very few breeding places

occurring among the bungalows, in the rains only, could very readily be abolished. In other places, less favourably situated, a complete absence of anopheles may be more difficult to secure, but those occurring are far less likely to be infected, and their destruction can scarcely ever be the herculean task presented by a large native town with many thousand inhabitants.

If with this condition of isolation at Victoriaborg we contrast the conditions in Freetown, we find that they could hardly be worse. European and native quarters exist side by side, and not infrequently a European may occupy the upper floor of a building of which natives occupy the dark cellars, which are a noxious feature of the dwellings totally unsuitable for Europeans there. The conditions of these houses are quite unsuited to tropical life; they are ill-constructed, surrounded by cess-pits, and have no verandahs. They are, in fact, most ill-adapted for life in a climate which is even more enervating than that of Accra.

In dealing with the question of anopheles in Freetown, we had to consider the conditions as we found them, and, as the most practical means for destroying the numerous breeding grounds of anopheles, we advised drainage. We should, however, lay more stress on the prime necessity for isolation, and, as it is under consideration to erect European dwellings in the adjoining hilly country, we consider that this is the only efficient way of dealing with the extremely dangerous conditions of existence there. We, however, would repeat again that, if this removal be carried into effect, strict attention must be paid to the proximity of native dwellings. It is not the elevated site in itself which will protect the Europeans there, for anopheles, as we have seen, exist in the hill districts of Freetown; it is the removal from the neighbourhood of the infected native. Consequently it is of prime importance that a native village be not allowed to spring up in connection with the European quarter, and the native quarters for servants should be removed as far as possible.

In Freetown isolation cannot fail to be most beneficial, and in the building of new houses, here and elsewhere, sites should be chosen which are as remote as possible from native quarters wherein the danger lies.

S. R. Christophers, M.B.
J. W. W. Stephens, M.D. Cantab.

Accra, Gold Coast,
May 17, 1900.

"Note on Certain Bodies found in the Glands of Two Species of Culex." Received June 8, 1900.

The first (fig. 2) were found in a culex commonly found in the bush in Sierra Leone. This culex was not found in Freetown itself. The bodies occurred in about 10 per cent. of this culex examined.

We have referred to these bodies, which have the characters of sporozoites, in our report on the distribution of anopheles in Sierra Leone. We have not so far succeeded in demonstrating a central stained spot (chromatin) as in sporozoites of *H. præcox*.

The second were found in from 5 per cent. to 10 per cent. of a species resembling *Culex pipiens* caught in a native village, together with anopheles and other culex species. So far we have found them in only one species of culex. In general, they are few in number, but in some portions of the gland they may be numerous. As many as half a dozen may occur in each globule of secretion. They may also occasionally be seen free in the salt solution. Their chief peculiarity is their straightness. Their nature remains so far undetermined.

J. W. W. STEPHENS, M.D. Cantab.
S. R. CHRISTOPHERS, M.B.

May 17, 1900.

"The Malaria of Expeditionary Forces and the Means of its Prevention." Received June 8, 1900.

In our report on "The Native as the Prime Agent in the Malarial Infection of Europeans" we have shown—

1. That in all native villages examined by us, from 50 to 90 per cent. of the children were infected with malaria. That a considerable portion of these infected children contained crescentic bodies, which very rapidly took on the spherical and flagellating form requisite for the transmission of human malaria to the mosquito.

2. That in all native villages examined by us anopheles were present. Nor were they absent when breeding places had not been in existence for varying periods up to three months. That, moreover, a certain proportion of these were always infected with the mosquito phase of the parasite. Not only the village as a whole, but each individual hut, in all but rare cases, contained both infected children and infected anopheles.

These conditions have been encountered by us in British Central

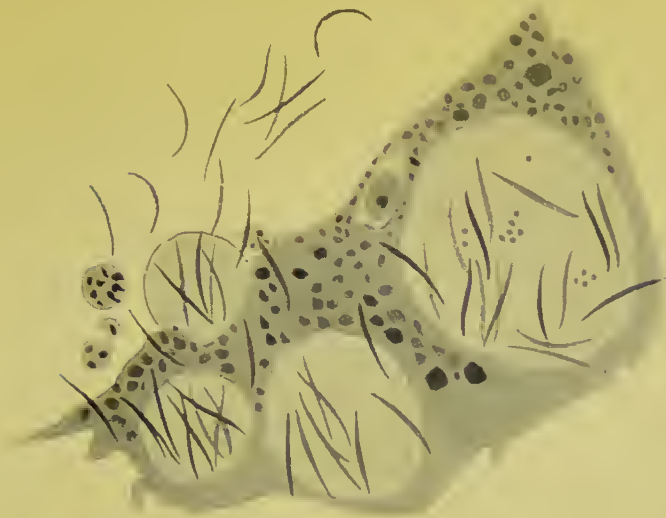


FIG. 1.—*Anopheles costalis.* Sporozoites of *H. præcox.* Fresh prep.

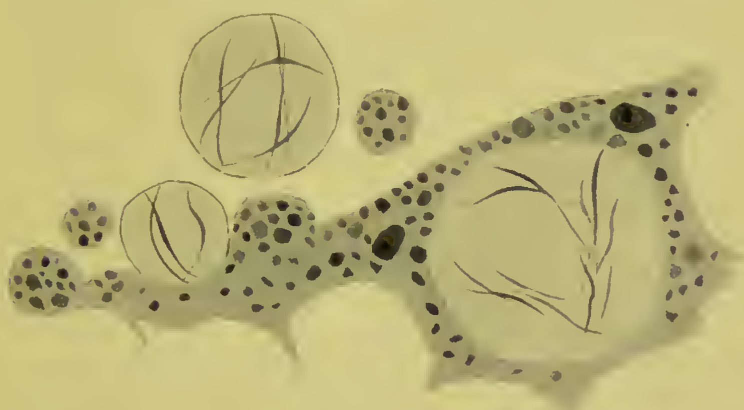


FIG. 2.—*Culex* (?). Sporozoites, nature unknown. Fresh prep.

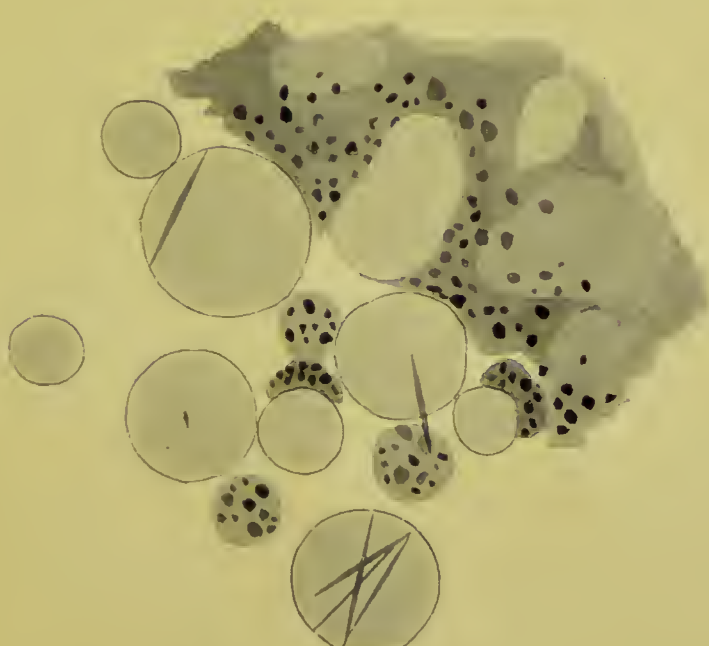


FIG. 3.—*Culex pipiens* (?). Bodies in secretion. Fresh prep.

Africa, Sierra Leone, and the Gold Coast, and there can be little doubt that they prevail universally throughout tropical Africa. These facts then are sufficient to explain why exploratory and military expeditions are attended with such a large amount of sickness and so terrible a mortality.

Very rarely does a traveller or expeditionary force pass for long distances through uninhabited districts; while even in the most remote, such as for example the Congo forests, villages exist. In a village not only are there food and other conveniences for native porters and even for Europeans, but they are also the only places where it is possible to find a ready-made clearing for a camp. Consequently it is the invariable practice for travellers and expeditions of all kinds to pitch their camps in the village clearing—if not to sleep in the village huts. For the single traveller there is usually no other alternative than to sleep, night after night at the end of each day's journey, in some native hut. Whether a hut is occupied, or whether a camp be pitched close beside the village, matters little; in either case infected anopheles, in greater or less number, are present.

So insidious, as a rule, are the attacks of anopheles, if few in number, that they attract very little attention.

Of the fever contracted in travelling we have in these conditions quite sufficient explanation. When night after night, for weeks or months, men, through sleeping in villages, are exposed to the bites of infected anopheles, it is quite evident that here we have the source of their sickness, and that it is unnecessary to call in the hypothetical influence of uninhabited swamps which they may have traversed. Assertions made by traveller's that they have, for many days running, camped by the side of uninhabited swamps, must be received with extreme caution. Such a method of camping is in tropical Africa, to say the least, both unusual and extraordinary.

Infection, then, can most certainly be escaped by a strict avoidance on the part of Europeans of native villages and huts. If native villages are of necessity selected as sleeping places, then, whilst in such places, the most scrupulous care should be observed in the use of mosquito nets, which should be under the vigilant supervision of the medical officer of the expedition. It is essential that they should be absolutely free from holes, and, further, that they should have a protective valance at the level of the body to prevent bites being effected through the net. A further modification of the net in general use is needed to suit the conditions where the traveller uses an ordinary camp bed or, as often happens, sleeps on the ground.

The danger of being bitten and infected in villages is so great that even the use of nets would probably not ensure complete protection. It is essential, therefore, that every endeavour should be made to camp elsewhere than in a native village. Villages are a certain source

of infection, and their avoidance will certainly result in a much diminished amount of malaria in expeditions.

J. W. W. STEPHENS, M.D. Cantab.
S. R. CHRISTOPHERS, M.B. Vict.

Note.—In a later letter from Mr. Christophers, dated "Accra, 26 May, 1900," further stress is laid on the fact that camping and sleeping in places *remote from human habitations* is in the highest degree exceptional in the case of European travellers and expeditionary forces. This fact, the writer thinks, is perhaps not sufficiently appreciated by persons not conversant with the conditions of African travel.

ERRATA.

In Report published July 6, 1900.

Page 62, line 18, *for* "titræ" *read* tibiæ.

,, 72, upper footnote, *for* 'Lancet' *read* 'British Medical Journal.'

REPORTS TO THE MALARIA COMMITTEE OF THE ROYAL SOCIETY, 1899–1900.

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REPORTS, &c., FROM Drs. STEPHENS AND CHRISTOPHERS, WEST COAST OF AFRICA.

"The Agglutination of Sporozoits. (Preliminary Note.)" By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received August 3, 1900.

It has been shown by Grabitschewsky for spirochetes and by Landsteiner for spermatozoa that with these bodies specific agglutinative reactions can be got.

We proceeded to investigate whether, under any conditions, sporozoits were capable of being agglutinated, and we have found that such is the case.

The salivary glands of anopheles were dissected out, and an emulsion was then readily made, either under a cover-glass, or in a hanging drop. In preparations made with normal saline the sporozoits float freely in the liquid. When, however, instead of using normal saline, human serum is used, we get the phenomenon of agglutination. The sporozoits concentrate more or less readily into masses, and after a certain time a few only are found free.

This reaction is shown with various low dilutions of normal serum.

Having shown that sporozoits are capable of agglutination, one might reasonably deduce that a truly specific action might be obtained between sporozoits and certain sera, as has been shown by Grabitschewsky and Landsteiner for spirochetes and spermatozoa, and as hold good very generally between an infective body and the resulting serum.

Our experiments in this direction are at present much hindered by the fact that only 2 per cent. to 3 per cent. of anopheles in Lagos contain sporozoits in the salivary glands. Such a specific serum we should expect to find in those constantly exposed to inoculation with sporozoits. Further, it may be possible that the serum of a malarial patient has such a specific action. We have already obtained an agglutination of sporozoits with such a serum in a dilution of 1 : 15 normal saline; whereas so far the action of normal serum has only been got in dilution of 1 : 5.

Further experiments are required before it can be shown that these reactions are definitely specific. If they be so, their bearing on the

questions of malarial immunity and possibly blackwater fever will be considerable.

We have further observed that sporozoits at ordinary room temperature (26°·5 C.) exhibit in serum active writhing movements, which continue for many hours. Further, in specimens kept in serum at 35° C. for twenty-four hours, many sporozoits become circular in shape, an appearance which appears to be due to the close apposition of the free ends of the sporozoit. Such forms stain readily, and then give the appearance of a ring with a mass of chromatin on the periphery, and a clear central area. The resemblance of these forms to the ring form of the parasite is striking, but whether accidental or not further observation must decide.

Lagos, West Coast of Africa,
July 14, 1900.

"The Malarial Infection of Native Children." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received October 1, 1900.

(PLATE 1.)

In a previous report we gave the results of our examination of the blood of a number of natives, having regard mainly to the relation between the age of the children and the percentage of those infected.

In this report we shall consider rather the character of the infection itself, and the variations that occur in it from time to time.

The difficulties experienced by us in obtaining the blood of native children has made this paper incomplete in many respects.

We shall consider the following points:—

1. Asexual forms (schizonts).
2. Sexual forms (gametes).
3. Leucocytic changes and pigment.
4. Periodicity of sexual and asexual cycles.
5. The immunity of adult natives.

It must be understood that in speaking of a case of malaria in children, we are referring only to the presence of parasites; the children are perfectly well, and present none of the characteristic signs observed in Europeans affected with malaria. In some cases, however, the temperature has reached 100° F., and further observations may show that the statement may require some qualification.

The parasite found by us so far, both in Lagos and on the Gold Coast, has been exclusively the æstivo-autumnal (malignant tertian) or tropical parasite of Koch. As altogether 639 cases have been examined by us without the occurrence of a single tertian or quartan parasite, we

believe that the latter forms do not exist among the natives of the West Coast. We think it very possible that certain forms of gametes bearing a superficial resemblance to tertians and quartans, and described by us later, have been so described by some authors. The asexual forms presented are quite characteristic. Thus we get the young forms, the so-called rings, with a stained chromatic body generally at some point on the periphery, and also the larger oval forms such as we have described in an early report; both these forms are unpigmented. We have never yet encountered a segmenting parasite in native blood, and we can only recall two instances in which we have seen segmenting parasites with a central pigment mass in European blood, and in both these cases the parasites were included in polynuclear leucocytes, and occurred in severe attacks of fever.

1. We have had, so far, no opportunity of following a case through a period of twenty-four or forty-eight hours, so are unable to state whether a tertian periodicity in the time of development of the schizonts is exhibited by the parasite in native children, as is the case in Europeans.

The asexual parasites, then, met with in the native blood are morphologically the same as those in Europeans, viz., æstivo-autumnal.

2. *The Sexual Forms* (*Makrogametes*, *Mikrogametocytes*).—It is here that native blood presents many points of divergence from European blood—features that have hitherto not been recorded. While in European blood subsequent to an attack of fever it is the crescentic form of the gamete that is encountered, in native blood while gametes are exceedingly common yet the crescentic form is rare, the gametes assuming the spherical forms found in simple tertians and quartans. At first we were inclined to think that here, owing to the climatic conditions, the change from the crescentic to the round form of the gamete occurred with peculiar rapidity—the change is known to be favoured by warmth and moisture; later it became evident that this would not explain the facts, as films made on dry days with the greatest rapidity showed the same absence of crescents, and, further, intermediate forms, such as would have been seen if the change were occurring on the slide, were not present. We are convinced, on the contrary, that the crescentic form is not an essential distinctive feature of the æstivo-autumnal parasite, but that in native blood the conditions are such that here, as in the case of the simple tertian and quartan parasites, male and female spherical gametes are present in the circulating blood.

Why in European blood, and occasionally also in native blood, crescentic forms are found, we have no facts to explain.*

* It may be well to briefly mention the technique adopted by us, for we think its simplicity recommends itself. In tropical work this is certainly a merit, for we know of excellent observers who are deterred simply by the multiplicity of details

In a stained preparation containing fully developed gametes, we are at once struck by the fact that these are of two kinds :—

(α) The mikrogametocyte (the male gamete) showing pigment collected in the centre, or occupying a narrow band across the central zone. The pigment is brownish yellow, lighter in the centre and spherical in shape. At the periphery of the gamete are a number of sharply stained bodies (chromasomes) roughly triangular in shape, and often showing a small central relatively unstained portion. The chromasomes are more or less regularly distributed peripherally. Frequently they are 12 or even 20 in number. (See Plate 1.)

(β) The makrogamete (the female gamete), showing pigment irregularly distributed over the whole of the gamete, spicular, dark, and quite easily distinguished from the pigment of the male gamete. The gamete is uniformly and only slightly tinged with stain, or at most shows one or two ill-defined deeper stained particles. It is not uncommon to find one or more "vacuolic" areas.

The differences in the distribution and in the character of the pigment in the two forms of gamete are well marked.

Celli in his description of the male and female gamete does not draw attention to this. Whether or no it occurs in European blood we do not know, but in native blood the difference is most characteristic.

The fact that in the mikrogametocyte we have always a central mass of pigment with a peripheral distribution of chromosomes, recalls the arrangement of a segmenting parasite. It seems reasonable to conclude that the chromasomes (mikrogametes) are really formed by a process analogous to that of segmentation and the formation of schizonts.

recommended by various authors. The finger is pricked with a triangular surgical needle and a clean glass slide made to touch the exuding drop of blood. The drop thus received on the slide is then spread by the shaft of the needle in a broad, even streak along the slide. On first touching the drop with the needle-shaft a little time should be given for the drop to run along the needle for some distance by capillarity. The most perfect films are thus obtained. The slides are then placed in a pot of absolute alcohol for five minutes. The merits of hæmatein (*purissimus*) as a stain for malarial parasite we have already pointed out. The beautiful results obtained in staining gametes confirms our original statements. A saturated alcoholic solution is made. To 10 c.c. of this solution are added 50 c.c. of alum solution (alum 50 grammes, water 1000 c.c.). The solution keeps for months, and does not precipitate stain. The stain is best kept in a pot and the slides dipped in. The slides may be left in some hours without over-staining, but excellent results are got in 5—20 minutes. The exquisitely clear chromatin staining often resembles results obtained by Romanowski's method.

On examination of a slide prepared in this way, the oil is applied directly to the slide without using a cover-glass. If it is required to preserve the specimen subsequently, the oil is washed off with a little xylol, and then Canada balsam and cover-glass applied to prevent the growth of mould. If the slides, however, are wrapped in clean paper in a closed box they are perfectly good without any cover-glasses a year later.

As a rule, the mikrogametocytes are in excess of the macrogametes. We have occasionally, however, seen instances in which no mikrogametocytes were found, but we believe that this is quite exceptional.

Frequency of Male and Female Gametes.

Case	I	♂ 5	♀ 3
,,	II	♂ 5	♀ 9
,,	III	♂ 2	♀ 1
,,	IV	♂ 3	♀ 4
,,	V	♂ 4	♀ 1
,,	VI	♂ 13	♀ 3
,,	VII	♂ 4	♀ 1
,,	VIII	♂ 0	♀ 2
,,	IX	♂ 17	♀ 9
	Total	♂ 53	♀ 33

The next peculiarity that we have noticed is the occurrence in very many of these bloods of immature forms of the gametes. According to Celli, these are only met with in European blood in the peripheral circulation in pernicious cases, otherwise they occur exclusively in the bone marrow. We were struck in examining the blood of native children by the occurrence of pigmented parasites of a type which we had not before seen, and by a closer examination it became evident that all stages of the pigmented forms occurred, very often together with the ordinary unpigmented ring forms, and that the former formed a gradation up to the typical gamete we have described. In the younger forms it is not easy to distinguish the differences of pigment that are characteristic of the adult forms, but it can often be seen that some of these stain more deeply than others, and already show a commencing formation of chromasomes. We find these forms about one-third the size of a red cell, and irregular in shape; from this they can be traced up to the adult form occupying the whole of the cell.

Again, we find in these bloods quite young forms not having the appearance of ordinary rings. As regards number, these non-annular forms are comparable only to the gametes, which in high degrees of infection are never so numerous as the ring forms. They stain uniformly around the periphery, and do not possess a chromatic body. They have usually a few fine grains of pigment. In their earliest form these bodies are unpigmented. We believe them to be the earliest stage in the development of gametes. Examples of these forms are seen in the accompanying plate.

We have, then, in native blood parasitic forms, *i.e.*, spherical forms of gametes and developmental forms of the same, which we do not

encounter in European blood. We believe that these forms have been wrongly described by some authors as tertians and quartans.

Not uncommonly the female gamete is associated with a well-marked stippling of the red cell in which it lies. The spots do not stain definitely, but they are large and easily seen. Whether this occurs in the case of male gametes we cannot positively state. The appearance of the red cell is a very characteristic and peculiar one.

3. *Leucocytes and Pigment.*—We have in various reports drawn attention to the marked mononuclear increase in malarial fever, and we have considered that the change is of considerable diagnostic importance. The change is, we think, to be regarded as an indication of reaction to infection, *i.e.*, as a sign of infection, not as a sign of immunity. Though the native child, as we have said, shows none of the characteristic symptoms of malaria, yet it is noticeable to what an extent this mononuclear change is marked in certain cases; in fact, it is uncommon in these young children, who are at some time or another always infected, to get a quite normal leucocytic value. The mononuclear increase is often extreme, in other cases slight. We give some examples in Table IV, though it has been impossible for us to follow out this change hourly as we have done in the case of Europeans. When the age of immunity is reached the high mononuclear value becomes normal, so that, although at this time there is a marked active immunity, there is no increase in the large mononuclear elements (see Table IV).

We would draw attention to the character of the pigment in the leucocytes. Sometimes this is of the spicular character noticed in the makrogamete; at other times we get isolated clumps, slightly granular in appearance, as if derived from the segmenting of schizonts. Occasionally we find the large mononuclears containing extremely fine dust-like pigment.

The presence of pigmented leucocytes we consider as evidence on the whole of the formation of schizonts, since numerous gametes may occur with few or no pigmented leucocytes. It is noteworthy, too, how extraordinarily difficult it is to find pigment in some slides, even along with a large parasitic infection. Search over large areas of blood-films is necessary before a negative result can be accepted as true. In native blood, pigment has never been observed by us in polynuclear leucocytes; in European blood, also, it is only in the more severe cases that it is found in these.

The extreme rarity, both in European and native blood, of parasites, included in leucocytes, is evidence that the action of the latter on the parasite cannot be phagocytic in the earlier sense of the word, as used by Metchnikoff. The parasite itself before or after its death is rarely seen included in the leucocytes, though it is quite possible that some secretory product of the leucocyte causes their destruction.

4. *Periodicity of Sexual and Asexual Cycles.*—We might have expected

that owing to the fact that the children in any particular house are constantly exposed to infection from anopheles, the blood examinations would show an infection of asexual parasites and gametes at different stages of development, and so mixed that no definite order or sequence could be evolved. But this is not so. An examination of the tables will give a more vivid idea of the nature, extent, and persistence of infection than a mere description could.

Table I shows at a glance the frequency with which gametes occur. Further, it appears that, contrary to expectation, there is a sequence in the occurrence of parasites. Thus, in Case I, asexual parasites and pigmented leucocytes only were found for a period of a month; then gametes appeared, and continued for about a fortnight, when further observations were discontinued.

Case II shows that asexual parasites and gametes practically co-existed for a period of over six weeks.

Case III. Gametes only were found during nine days' observations. Ten days later asexual parasites first appeared and continued without gametes for nearly a month, when gametes again reappeared without the disappearance of the asexual parasites.

Case V. Gametes persisted for a month with an occasional appearance of asexual parasites.

So that it would appear as if there was a succession of gametes, in the same way as we have a succession of developments of asexual parasites leading to the ordinary febrile attacks of Europeans. In Case III there is apparently about a month between the appearance of two gamete cycles; but this may be accidental, as observations were not prolonged over a sufficient number of months and in a sufficient number of cases to establish this interval with any certainty.

Table II shows the same thing in children from a less highly infected area; whilst Table III shows it where immunity due to age is producing weaker infections.

The appearance of gametes (crescents) following on the asexual (schizont) cycle in European fevers must be regarded as the expression of the regular periodicity of the cycles, some indications of which we believe are afforded by this examination of native blood.

The time of persistence of the schizont and gamete cycles cannot well be observed in Europeans, as the periodicity is interfered with by quinine, but we have in these children an indication of the cycle which leads to the fortnightly or monthly fevers which have been described in Europeans.*

We cannot, in the present state of our knowledge, attribute any part to the gametes in the production of relapses.

It has been hitherto generally accepted that the gamete (crescent)

* "On peut dire d'une façon générale que les rechutes ont lieu souvent à la fin des septénaires." Laveran, 'Traité du Paludisme," p. 165.

was peculiarly resistant to quinine; but as we no longer can attribute to them this function of producing relapses, it must follow that the parasite in some form can exist in a cinchonised body, probably in the internal organs. It has too often been assumed that the absence of parasites in the peripheral blood signifies an absence of malarial infection, but in native children, as we have seen, a negative blood examination on a particular day is frequently followed by a positive on the subsequent one, and it is not an uncommon experience that Europeans habitually using quinine may suffer from slight fever attacks (in all probability malarial) in which parasites are very scanty or absent.

If we consider generally the condition of infection of natives, we see that we have two conditions :—

(1) A condition of infection of young children without febrile disturbance. This may be due to a natural insusceptibility of the native African to malaria, or it may be due to an immunity transmitted from the parent to the offspring. This question could be best determined by observing whether a child from a non-endemic area would, on introduction to an endemic area, suffer from typical symptoms as a result of infection.

(2) We have further a condition of active immunity in the adult native, an immunity acquired as the result of many years (10) of infection with parasites. The immunity is accompanied (see Table III) by a progressively scantier development of parasites, and is quite comparable to that described by Pawlowsky* for infection with micro-organisms.

Whether the serum of such an immune person would have any curative properties, and what reactions *in vitro*, agglutinative or parasiticidal, it might possess, further observations are necessary to determine.

Native malaria is a field of study hitherto completely neglected. Prolonged observation of native children, with post-mortem examinations, cannot fail to throw much light on the life-history of the parasite in the human organism.

* A. O. Pawlowsky, "Zur Frage der Infection und der Immunität," 'Zeitschrift für Hygiene und Infections-Krankheiten. Drei und dreissigster Band. Zweites Heft,' 1900.

TABLE I.—Showing Course of Infection in Native Children (highly endemic area).

	Case I, 4 y.	Case II, 4 y.	Case III, $\frac{4}{12}$ y.	Case IV, 3 y.	Case V, $\frac{6}{12}$ y.	Case VI, 5 y.	Case VII, 2 y.	Case VIII, 5 y.	Case IX, 4 y.
26 : VI : 00	P^{1} — $L^{f.n.}$	— — $L^{f.}$	— $G^{n.}$ $L^{n.}$	—	— $G^{n.}$ —	—	Neg.— —	—	— — L^{1}
29 : VI : 00	— — L^{1}	—	— $G^{n.}$ $L^{f.}$	—	— $G^{n.}$ —	—	—	—	—
30 : VI : 00	$P^{n.}$ — —	P^{1} G L	— $G^{n.}$ $L^{f.}$	—	—	— G^{1} —	Neg — —	—	—
5 : VII : 00	—	Neg.— —	— G^{2} L^{4}	—	— $G^{v.n.}$ —	— — L^{1}	Neg.— —	—	Neg.— —
8 : VII : 00	$P^{n.}$ — —	— — L^{1}	— — $L^{f.}$	—	$P^{f.}$ $G^{f.}$ —	$P^{n.}$ — —	—	—	—
15 : VII : 00	$P^{v.n.}$— —	P^{5} G^{3} $L^{f.}$	$P^{f.}$ — —	$P^{f.}$ — L^{2}	— G^{1} L^{1}	P^{2} — —	$P^{f.n.}$— —	$P^{n.}$ G^{1} L^{1}	$P^{n.}$ — —
22 : VII : 00	$P^{v.f.}$— L^{1}	$P^{n.}$ $G^{n.}$ L^{4}	$P^{f.n.}$— —	$P^{v.n.}$— L^{1}	$P^{f.}$ $G^{v.n.}$ L^{3}	$P^{f.}$ — —	$P^{v.f.}$— L^{1}	— $G^{f.}$ —	$P^{f.}$ — —
26 : VII : 00	$P^{f.}$ — L^{2}	P^{1} G^{1} L^{3}	— — L^{2}	— — L^{2}	—	Neg.— —	$P^{f.}$ — —	—	$P^{v.n.}$— —
29 : VII : 00	— $G^{f.}$ —	—	P^{2} — L^{3}	P^{2} — —	— $G^{v.n.}$ —	Neg.— —	Neg.— —	— $G^{v.n.}$—	P^{4} — —
1 : VIII : 00	Neg.— —	— $G^{f.}$ L^{4}	P^{3} — —	$P^{v.n.}$ G^{1} $L^{f.}$	— G^{4} —	Neg.— —	$P^{n.}$ G^{1} —	P^{2} — —	Neg.— —
3 : VIII : 00	—	$P^{f.n.}$ G^{2} L^{2}	— — L^{3}	$P^{v.n.}$— —	P^{5} — L^{1}	P^{4} — —	— G^{3} L^{2}	Neg,— —	Neg.— —
5 : VIII : 00	$P^{f.n.}$ G^{8} —	$P^{n.}$ G^{1} L^{8}	P^{2} — —	$P^{n.}$ G^{2} —	Neg.— —	$P^{n.}$ — —	$P^{f.n.}$ $G^{6.}$ —	Neg.— —	P^{2} — —
7 : VIII : 00	$P^{f.}$ G^{9} —	$P^{n.}$ — L^{1}	$P^{v.n.}$— —	P^{4} — L^{1}	$P^{v.n.}$— —	P^{5} — —	P^{4} G^{1} —	— G^{1} —	$P^{f.}$ — —
10 : VIII : 00	P^{2} $G^{n.}$ L^{4}	$P^{f.n.}$ G^{6} L^{16}	— G^{2} —	P^{2} G^{1} L^{1}	—	Neg.— —	P^{5} — L^{1}	— G^{1} —	— G^{1} —
12 : VIII : 00	P^{2} G^{1} —	$P^{v.n.}$— —	$P^{f.n.}$ G^{5} L^{10}	P^{1} G^{1} —	P^{4} G^{3} L^{4}	P^{1} G^{2} —	P^{10} G^{1} L^{1}	P^{1} G^{2} —	$P^{f.}$ — —
14 : VIII : 00	P^{1} — —	— G^{1} L^{3}	$P^{f.n.}$ G^{2} L^{12}	$P^{n.}$ — —	—	Neg.— —	Neg.— —	Neg.— —	Neg.— —
16 : VIII : 00	Neg.— —	— G^{2} L^{2}	P^{3} — —	—	— G^{10} —	—	—	—	Neg.— —

P = asexual parasite. G = gamete. L = pigmented leucocyte. n = numerous; f.n. = fairly numerous; v.n. = very numerous; f = few; the numbers 1, 2, 3, &c., denote how many parasites, &c., found.

Table II.—Showing Course of Infection in Native Children; the infection is less than in Table I, the children coming from a less endemic area.

	Case I, 2 y.	Case II, 8 y.	Case III, 9 y.	Case IV, 3 y.	Case V, 5 y.	Case VI, 2 y.	Case VII, 5 y.	Case VIII, 4 y.	Case IX, 8 y.
4 : VIII : 00	$P^{f.n.}$ — L^1	— G^n L^1	$P^{v.n}$ — L^1	P^6 — —	$P^{f.n.}$ — L^2	$P^{n.}$ — —	P^5 — L^1	$P^{f.}$ — —	—
5 : VIII : 00	P^5 G^3 —	$P^{v.n.}$ — —	P^7 — —	— — L^2	P^n — —	P^8 G^2 —	P^5 — —	—	Neg. — —
6 : VIII : 00	P^2 G^1 L^8	$P^{v.n.}$ — —	P^1 — L^1	Neg. — —	P^5 — —	—	—	$P^{f.n.}$ — —	P^2 — —
7 : VIII : 00	P^3 — —	Neg. — —	Neg. — —	Neg. — —	—	$P^{n.}$ $G^{n.}$ L^2	— G^1 —	$P^{f.}$ G^1 —	—
8 : VIII : 00	P^5 — —	P^3 — —	Neg. — —	Neg. — —	P^2 — —	$P^{f.}$ G^8 —	P^3 — —	P^{12} — L^1	Neg. — —
9 : VIII : 00	P^1 — L^2	Neg. — —	Neg. — —	Neg. — —	Neg. — —	$P^{f.}$ $G^{n.}$ —	P^2 — L^1	—	— — L^1
10 : VIII : 00	Neg. — —	—	—	—	—	—	—	—	—
11 : VIII : 00	—	Neg. — —	Neg. — —	Neg. — —	Neg. — —	P^1 G^{16} L^2	P^3 — —	—	Neg. — —
12 : VIII : 00	Neg. — —	Neg. — —	—	Neg. — —	—	— G^2 —	— G^7 —	—	Neg. — —
13 : VIII : 00	Neg. — —	— G^1 —	—	Neg. — —	P^4 — —	— G^2 L^4	— G^3 L^5	$P^{n.}$ — L^3	Neg. — —
14 : VIII : 00	Neg. — —	Neg. — —	Neg. — —	P^5 — —	— — L^2	— — L^2	— — L^4	—	Neg. — —
15 : VIII : 00	—	Neg. — —	—	P^2 — —	P^2 — L^1	— G^3 L^1	— G^1 —	P^f — L^2	Neg. — —
17 : VIII : 00	P^3 — —	Neg. — —	Neg. — —	Neg. — —	P^1 — —	P^1 G^1 —	— G^1 —	Neg. — —	P^2 — —

Table III.—Showing Diminution of Infection with increase in Age.

	31 : VII : 00.			2 : VIII : 00.			8 : VIII : 00.			14 : VIII : 00.		
Case I, 6 y.	P^4	—	—	—	G^3	—	P^3	—	—		—	
,, II, 8 y.	—	—	L^3		—			—			—	
,, III, 4 y.	P^3	—	—	—	G^8	—	Neg.	—	—		—	
,, IV, 5 y.	—	G^9	—	—	G^3	—		—			—	
,, V, 6 y.	—	G^5	—	Neg.	—	—	—	G^1	—	—	—	L^3
,, VI, 7 y.	P^5	—	—	Neg.	—	—		—		Neg.	—	—
,, VII, 6 y.	—	G^1	—	Neg.	—	—		—			—	
,, VIII, 6 y.	Neg.	—	—	Neg.	—	—	—	G^2	—		—	
,, IX, 6 y.	Neg.	—	—	Neg.	—	—	—	G^1	L^1		—	
,, X, 7½ y.	P^1	G^1	—	P^4	—	—	—	G^1	L^1	—	—	L^1
,, XI, 6½ y.	—	G^3	—	—	G^2	—	Neg.	—	—	P^4	—	—
,, XII, 7 y.	P^1	G^1	L^1	Neg.	—	—	Neg.	—	—	Neg.	—	—
,, XIII, 5 y.	P^1	G^3	—	—	G^1	—	—	—	L^2	Neg.	—	—
,, XIV, 6 y.	$P^{f.n.}$	—	—	—	G^2	—	P^6	G^2	—	P^6	—	—
,, XV, 6½ y.	Neg.	—	—	Neg.	—	—	Neg.	—	—		—	
,, XVI, 5 y.	—	—	L^6		—		P^2	—	—		—	
,, XVII, 4½ y.	—	G^1	L^4		—		P^1	—	L^3		—	
,, XVIII, 5 y.	—	—	L^1	Neg.	—	—	P^7	G^7	—		—	
,, XIX, 7½ y.	—	$G^{f.n.}$	—	P^3	—	—	$P^{f.n.}$	G^5	L^2	—	G^1	—
,, XX, 6½ y.	—	—	L^3	P^5	G^2	—	—	—	L^4	—	—	L^3
,, XXI, 4½ y.	Neg.	—	—		—			—			—	
,, XXII, 8½ y.	Neg.	—	—		—		Neg.	—	—		—	
,, XXIII, 5½ y.	—	$G^{f.n.}$	—	$P^{f.n.}$	—	—	P^1	—	—	—	—	L^1

Table IV.—Showing Leucocytic Changes in Native Children.

Age.	Nature of infection.	Large mononuclear.	Polynuclear.	Small mononuclear.	Eosinophyl.	Remarks.
$\frac{8}{12}$	$\mathrm{G}^{\text{scanty}}$	24	24	45	7	Young children; showing parasites.
$\frac{10}{12}$	— — L	26	24	49	1	
2	$\mathrm{P}^{\text{n.}}$ — $\mathrm{L}^{\text{n.}}$	30·6	23·6	41	4·6	
3	$\mathrm{P}^{\text{n.}}$ — —	21·3	48·6	26	4	
3	$\mathrm{P}^{\text{n.}}$ — $\mathrm{L}^{\text{n.}}$	52	26	19	3	
5	— $\mathrm{G}^{\text{sc.}}$ $\mathrm{L}^{\text{n.}}$	34·5	33	24	8·5	
3	— $\mathrm{G}^{\text{sc.}}$ $\mathrm{L}^{\text{sc.}}$	30	42	27	1	
5	$\mathrm{P}^{\text{n.}}$ — $\mathrm{L}^{\text{sc.}}$	19	47	22	12	
1	neg.	13·2	63	22·2	1·2	Young children; showing no parasites in blood.
2	neg.	12	32	44	12	
3	neg.	24	39	34·5	1·5	
4	neg.	24·5	49	24·5	2	
9	$\mathrm{P}^{\text{sc.}}$ — L	25	36	29	7·5	Limit of age at which infection takes place.
10	$\mathrm{G}^{\text{scanty}}$	24	40	26	9	
11	neg.	16·5	40	16·5	16·5	
12	neg.	12	37	34	17	
20	neg.	8·2	69	18·5	5·2	Adults.
22	neg.	13	65·4	13·1	8·5	

"On the Destruction of Anopheles in Lagos." By J. W. W. STEPHENS, M.D. Cantab, and S. R. CHRISTOPHERS, M.B. Vict.

Received October 1, 1900.

[PLATE 2.]

In most towns and villages in the rainy season small pools are numerous, and water oozes from the ground in many places. At this time the breeding places of anopheles abound. They are more

numerous in towns than would appear from a carefully made "spot map," for they are easily overlooked in native enclosures and other sites difficult of access; and, again, new pools are formed, and others previously free may on a second visit contain larvæ.

In the dry season the conditions are very different. Late in the dry season, prolonged search may be necessary before any breeding places can be found, and indeed large areas may not contain a single breeding place. Mere observation of breeding places has led to totally erroneous ideas as to the real distribution of anopheles at this time. The few existing pools give an inadequate idea of the number of anopheles in a district. There may be many thousands of winged anopheles widely distributed not originating from the scanty stock of breeding places then present, but remaining over ("hibernating") months after the pools they were bred in have disappeared. At the end of the dry season, the real distribution of anopheles would be indicated by a spot map showing the native huts of a district. In nearly every hut anopheles can be found by one practised in detecting them: feeding at night on the inmates, and secreted by day in the dirty thatch, they pass through much or the whole of the dry season without breeding. We have in a previous report given many examples of this condition. It will suffice here to recall those of Freetown and Accra, where, although the number of pools was very small, anopheles were present throughout the greater portion of the town, and always ready to lay their eggs in the artificial (test) pools constructed by us.

In spite, then, of the at first sight promising conditions during the dry season, it is doubtful whether at this time it is possible to influence the number of anopheles in the ensuing rains. To destroy breeding places in the dry season would in many places be an easy task, but unless destructive measures are capable of keeping a decided check on breeding places when they are most numerous, *i.e.*, in the rains, efforts to diminish anopheles will probably not have any appreciable effect.

Physical Features of Lagos.

Lagos is situated upon low-lying alluvium, and is surrounded by extensive lagoons. The western half of the small island of Lagos is completely occupied by the town, the native huts in some places extending to the water's edge. Several small lagoons penetrate into the island, and are shown on the accompanying map. (Plate 2.) Around each of these sheets of water we find very numerous and squalid huts.

The whole island of Lagos is low lying, the highest point not being above 20 feet above sea level. A considerable tract, however, in the centre of the town lies above 10 feet above sea level. This central comparatively elevated area is approximately level, but its margins sink rapidly towards the lagoons. Between this sloping ground and

the lagoons there is a strip of land of varying width which lies almost at lagoon level. The extent of this strip of low land is shown by the 5-foot contour line on the accompanying map of Lagos.

The ground upon which the town is built consists of porous sand. Even the heaviest rain is rapidly absorbed in the central elevated tract; so that in a few days after continuous rain, all surface pools have disappeared. The subsiding water, however, emerges again around the borders of this tract, forming a line of oozing water extending around nearly the whole island after the main rains. The upper limit of this line did not rise above the 5-foot contour line.

Anopheles Breeding Places.

The distribution of the water described above determines very largely the distribution of anopheles breeding places. On the higher ground, owing to the transient nature of the pools, breeding places are very rare and last but a short time. Below the upper limit of the oozing water, however, breeding places are present everywhere in large numbers. The marginal strip of low ground especially is the site of extremely numerous breeding grounds, and it is where this strip is broadest that anopheles are present in greatest profusion.

Mention has been made of several minor lagoons which extend into the island of Lagos. Around the margin of these the low level strip reaches its greatest extent. Much of the ground is land reclaimed by the deposition of mud, shell banks and refuse. This land is barely above the level of the lagoon water, and is completely waterlogged. It is everywhere covered with innumerable pools and puddles, very many of which contain anopheles larvæ. The number of pools is so great that there is no limit to the number of anopheles that might be produced, and the actual resulting number is probably determined by the food supply of the adults or other causes.

The pools here also are not always of a permanent nature, and the breeding places vary from week to week. The accompanying map shows those breeding places seen in a single week in July. They do not, however, represent the total number, as owing to the extent of water and the boggy nature of the ground the pools were often difficult of access.

In the less densely populated portions of the strip small maize gardens are common. In the furrows of these, anopheles are always abundant. In this portion of the town it is also a common thing to find anopheles larvæ in shallow earthenware vessels which are not in use but which contain rain-water.

On reaching the higher ground above the narrow strip described, a very marked difference in the number of breeding places is at once evident.

The Lagoons.—As the small lagoons themselves were shallow it was thought possible that anopheles bred in these also. They were never detected, however, by us, though careful search was made.

An examination of the salinity of these lagoons showed that the salt was inconsiderable, and indeed fell short of that in wells in Accra in which larvæ abounded.

It is probable that it is on account of the open nature of these large sheets of water that anopheles do not breed in them. In small pools upon the mud, separated by only a few inches from the open water, larvæ are, however, sometimes present.

The Destruction of Breeding Places.

The following is an ennumeration of the chief sources of anopheles in Lagos:—

1. The strip of land surrounding the following lagoons:—
   Isalegangan lagoon,
   Indumagbo ,,
   Alakaro ,,
   also a tract of swamp and small lagoons along the N.E. shore of Lagos.
2. The district of Ehin Igbeti.
3. The swamp margins and low-lying districts to the east of Lagos.
4. Occasional temporary pools in the streets after heavy rains.

No. 1 includes the main portion of the breeding grounds of Lagos. These areas consist almost entirely of ground such as has already been described, namely, waterlogged land abounding in pools and breeding places and densely crowded with native huts.

To deal effectively with such extensive areas is a work of great magnitude. Culicides could not be employed effectively. Drainage must be almost impossible. The only method which appears at all feasible is filling with sand. We have seen that, even in the heaviest rains, water does not ooze from the ground except at a level below 5 feet above sea level. Were then the whole low-level strip raised by the deposition of some porous substance (sand) to the height of 5 feet, the required result would be obtained. The surface water from the areas above this level then, especially if facilities for its doing so were increased by pipes or other means, would reach the open lagoon without appearing at the surface. There would be no necessity to advance far into the shallow lagoons, as we have seen that it is only on their shores that breeding places occur.

At the present time a swamp is being filled by sand in this way; and were this process persevered in no doubt in time the western

portion of Lagos Island, upon which the town is built, could be freed from areas at present giving rise to myriads of anopheles.

Even if no attempt be made to do away with such low lands in towns, the reclaiming of lagoons and the making of new waterlogged land by the deposition of rubbish, shells, and mud cannot be too strongly condemned. In Lagos there are at present considerable tracts of land that have been formed in this way, and these are always conspicuous as the breeding places of anopheles.

No. 2. Ehin Igbeti is chiefly of interest in that it is the district which supplies the anopheles which frequent the majority of the European houses in Lagos. It is a tract of swampy ground, not very extensive, lying behind the houses on the Marina. The extent of this area can be judged from the accompanying map. This area, as it is the nearest to European quarters, should be the first of the sources to be abolished, whilst the extensive areas just discussed are for the most part a considerable distance from these. Ehin Igbeti is not so low as the swampy ground around the lagoons, though it is less than 5 feet above sea level. The filling up and increased drainage of this source of anopheles ought to be both a very practicable and advantageous proceeding.

No. 3, a very extensive swamp, is situated to the east of Lagos. Around its borders are very numerous breeding places. This region would present great difficulties to any method of treatment. There is also towards the eastern end of Lagos an area of low ground with breeding places lying close behind the hospital, prison, and European quarters which could, by combined filling up and drainage, be removed fairly readily.

No. 4. The temporary pools formed during the heavy rains on the more elevated grounds are by no means numerous. Of the numerous cement gutters in the town the majority are free from breeding places, being scoured out by the least rain. In certain places gutters with irregular bottoms have been formed; these, as well as gutters needing repair, very frequently have breeding places. Apart from the gutters, however, pools are liable to form on the sandy surface of the roads, but these, as will be seen from the map, are not nearly so numerous as those in the special districts described above.

The Result of Destructive Operations.

Were this thorough treatment carried out, could we be sure that anopheles would disappear and malaria be absent?

We have seen that the central high portions of Lagos are very free from breeding places, and except in the height of the rains it is a most difficult matter to find any at all. In this locality we should expect, then, a diminution in the endemic malaria present, as shown by a

lessened percentage of infected children. The result of the examination of children from various districts in Lagos is shown in the following table and the map. (Plate 2.)

Table I.—Showing Endemic Malaria of Lagos.

District.	Age.	Percentage infected.
Olowogbo	Below 2 years ..	62·5
	2—5 years	66·6
	5—10 years	—
Massey Square	Below 2 years ..	71·4
	2—5 years	50·0
	5—10 years	—
Market Square	Below 2 years ..	100·0
	2—5 years	71·4
	5—10 years	—
Balogun Square............	Below 2 years ..	—
	2—5 years	70·0
	5—10 years	—
Cow Lane District..........	Below 2 years ..	80·0
	2—5 years	75·0
	5—10 years	25·0
Strictly limited central area as shown on map.	Below 2 years ..	50·
	2—5 years	40·0
	5—10 years	—

It is evident that there is a slight diminution in the percentage of infected children, but by no means a marked one. How far, then, the most complete operations will affect the malaria of a large town we hesitate to say. There may be a certain number of anopheles in the higher portions of Lagos derived from the numerous wells scattered throughout the town. We were, however, unable to detect larvæ in those examined by us, which for the most part contained deeper and purer water than the wells of Accra. Possibly some spread of anopheles takes place from the periphery of Lagos to the centre. So closely associated indeed are malaria and the native in Africa, and so wonderfully constant is the presence of anopheles where natives are collected in numbers, that we doubt whether any operations, now possible, directed against anopheles will do much to diminish the

danger of malarial infection. In fact, in Africa the primary aim should not be the destruction of anopheles, but rather to remove susceptible Europeans from the midst of malaria. To stamp out native malaria is at present chimerical, and every effort should rather be turned to the protection of Europeans.

"Note on Malarial Fever Contracted on Railways (under Construction)." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received October 1, 1900.

[PLATE 3.]

The railway camps, plans of which accompany this note, afford a particularly good example of the conditions under which malaria is contracted.* The requisite conditions are :—

1. Native children supplying the infection.
2. Infected anopheles in the native huts.
3. Collections of huts inhabited by adult natives also favour the transmission of malaria, as although the source of infection may be more distant, yet anopheles infected elsewhere abound in such huts.

In railway camps we have all these conditions in the immediate vicinity of the European dwellings, and they completely explain the prevalence of fever in these camps.

The conditions shown in the plans were present in every camp without exception on the Lagos Government Railway.

Plan I is that of Aro, at present the terminus of the Lagos Government Railway. It shows (1) native servants' quarters, (2) labourers' camp, (3) native villages. All these contained numerous anopheles, and the number containing sporozoits was at least 25 per cent. Although the native servants' quarters did not contain many children, yet migration of infected anopheles undoubtedly took place, as shown by the arrows on the plan. They thus supplied condition 3.

Plan II. Loko Meji Camp: Numerous native servants and a few women and children live in the huts immediately adjoining those of the Europeans. About 50 per cent. of anopheles caught in these huts were infected. A considerable native village within a distance of 200 yards contained numerous children and infected anopheles.

Plan III. Railhead Camp: occupied by a single European. The same conditions—children, native servants, infected anopheles, native villages close at hand.

* *Vide* "The Native as the Prime Agent in Malarial Infection of Europeans," also "Segregation of Europeans," in our Reports to the Malarial Committee of the Royal Society.

Prevention of Malaria.

In our report entitled "Segregation of Europeans" (see below), we discuss fully how protection from malaria is to be obtained, and there conclude that the only practical fundamental means is a complete segregation of Europeans from all natives.

This, however difficult in the case of towns, can be easily effected without expense on any railway under construction.

Plan IV illustrates how this can be done.

1. A site should be selected for European dwellings as far as possible from a native village; a mile would undoubtedly suffice.

2. The camp of the native labourers should also be placed at the greatest possible distance (half a mile to a mile).

3. The house servants and others should not sleep in the European compound, but a quarter to half a mile away.

4. One personal servant only should be allowed to remain in the camp at night.

There is nothing impossible in these conditions, and were the medical officer to have the selection of sites and the power to see that segregation was as far as possible carried out, malaria would be far from being so rampant on railways as it now is.

"The Segregation of Europeans." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received October 1, 1900.

Koch* has shown that while the native adults of Dutch New Guinea do not suffer from malaria, yet that malarial infection in certain districts among children is a general condition, the percentage of infected cases sometimes being as high as 100 per cent. He also showed that as the age of the children increased the percentage of infected children diminished, so that above the age of ten the immunity of the children was already very great. In this condition of infection of young children we have, further, an accurate index of the endemicity of malaria.

Working independently on the Gold Coast we, too, found† that the infection of native children was a widespread and general condition—that there the age-factor was that which determined the existence or not of infection.

* Koch, "Dritter Bericht über die Thätigkeit der Malaria-Expedition," 'Deutsche. Med. Woch.,' Nos. 17 und 18, 1900.

† Stephens and Christophers, "The Native as the Prime Agent in the Malarial Infection of Europeans." ('Further Reports to Malaria Committee 1900).'

It must be clearly recognised, however, that although we are dealing here with a blood infection, yet the condition is not that which we find in Europeans suffering from malaria. Although parasites are present in both cases, here the similarity ends, for, speaking generally, the children in whose blood there may be very numerous parasites do not appear ill. They run about or attend school, and present none of the well-known symptoms of a malarial attack. Further, this condition, viz., the presence of parasites, is not a transient one, but persists for weeks, months, and, in fact, years. We do not imply that the number of parasites is always the same; on the contrary, it is most variable; but if parasites are not present one day they will be found the next, or the interval in which parasites do not occur may be longer; but, speaking broadly, the condition is one of a constant infection until the age-limit at which immunity appears is reached.

We would appear to have, then, in this condition of infection of native children unaccompanied by manifest signs a state of things parallel to that of trypanosoma in wild game and in rats, and of halteridium in birds.

The parasite found by us so far in native children in Lagos and on the Gold Coast has been the malignant tertian (æstivo-autumnal), and, indeed, out of several hundred cases not a single quartan or simple tertian occurred. The frequency with which gametes occur is very striking, so that the constant presence of infected anopheles in native quarters, as already shown by us, is readily explained.

In the case of Europeans, on the contrary, parasites are rarely found except in definite attacks of fever. Even when present they are extremely few in number, and bear no comparison to the large infections with the ring-form parasites, or with gametes, of native children. An examination of a number of Europeans living in Lagos and in various stations up country showed how at any one time but a very small percentage showed the least trace of malarial infection. Even in the case of Europeans who habitually slept without mosquito nets, and exposed to the risk of constant infection, the same paucity of infection was exhibited. Of twenty-one such Europeans only two showed parasites, and these were in both cases of extreme rarity. Of a considerable number of Government officials and other Europeans who habitually used nets and adopted ordinary precautions, none contained parasites.

These facts are of importance, as they show that the generally-received idea that Europeans derive malaria from pre-existing cases in Europeans requires considerable modification. This factor, it seems to us, sinks into complete insignificance beside that of infection derived from native sources. The normal condition of native children is one of almost continuous infection, and there are therefore many thousands of cases of malaria in large towns. This enormous source of infection has so far escaped recognition. Whilst Europeans live in the midst of

native quarters exposed to infection on all sides, the isolation of such Europeans as may have fever, as has been and is still advocated by some writers, is manifestly futile.

It cannot be too clearly realised by Europeans in these large towns and by those responsible for their health that they are dwelling in the midst of thousands of cases of malaria, none the less dangerous to them though in the native child presenting none of the characteristic signs of an attack of "fever." Malaria is essentially a contagious disease, the contagion being conveyed by the mosquito; the laity must appreciate this fact and refuse to dwell in the midst of contagion. They must recognise that malarial fever is a contagious disease contracted (through the medium of the mosquito) from the native child. Malarial fever, we are convinced, can be avoided most readily by avoiding this source of contagion and living as far removed as possible from native huts. Just as a horse cannot live in a "fly" district, as he becomes inoculated with the fatal tsetse-fly disease by the contagion conveyed from the wild game, so the European living among native children is inoculated by means of the mosquito with malarial fever. The only means of escape is by segregation to avoid the source of contagion.

Hitherto attention has been confined almost entirely to ridding whole towns of anopheles. We are of opinion, from observations recorded in another report, that this is by no means the easy task supposed by many, and that it is likely to be brought about only after many years of gradual improvement in the surface drainage of towns Now, the adult native possesses, as we have seen, an active immunity against malaria, and although living under the same conditions as the children, constantly subjected to the bites of infected anopheles, yet examination of his blood shows that parasites are always absent. It is true that the immunity is not absolute, for occasionally we meet with severe fatal attacks in adults, but, speaking generally, there can be no doubt of the real immunity enjoyed by the adult native.

There is no doubt, then, that to the adult natives of African towns the presence or absence of anopheles is by no means so important a matter as it is to Europeans. The question that is of the most urgent necessity, then, is not so much how large towns with sometimes 40,000 native inhabitants can be freed from anopheles, but how the comparatively small number (at most 200) of Europeans can be protected.

This, we believe, is only to be attained by segregation of the Europeans. In constructing new European houses, the main point to consider is how can they be placed as far as possible from native dwellings. Where a distance of one-quarter to half a mile can be placed between European residences and any native hut, malaria must of necessity become rare.

In Freetown we believe that the segregation of Europeans is only possible by the removal of the whole of the European residences from Free-

town itself; and the proposal to build residences on the adjacent hills is an excellent one, provided the greatest care be taken that no native quarters are in the neighbourhood. If things, however, are allowed to take their course, the new condition may well be worse than the old. For at once quarters for native servants and their families spring up around each European residence, and so the mistake universal on the coast and responsible for nine-tenths of the malaria is perpetuated, namely, living amidst native huts in which malaria and infected anopheles may at all times be found.

At Accra the partial segregation of official quarters has been effected, and we believe with the best results.

In Lagos, finally, if the official and other residences are removed to some up-country station on the railway, as has on several occasions been suggested, again it cannot be too urgently insisted on that on no pretext whatever should residences be built near any native quarter, or that native quarters be allowed to spring up in the midst of the new European quarter. Otherwise the inevitable result will be that malarial fever, contracted from the native children, will be as rife, if not more so, as it is in Lagos at present.

The rigorous isolation of Europeans from natives is, then, the most practical and fundamental means of diminishing the danger of malarial infection. In Africa a complete isolation of Europeans would, we believe, render malaria a comparatively rare disease.

PLATE 1.

To illustrate paper on Malaria in Native Children.

Description :—

1. Young form of Gamete.

2, 3, 4. Older forms of the same.

5. Makrogamete.

6. Mikrogametocyte.

7, 8. Makrogametes showing punctation of red cell in which they are situated.

9, 10, 11. Types of pigmented leucocytes met with in native children.

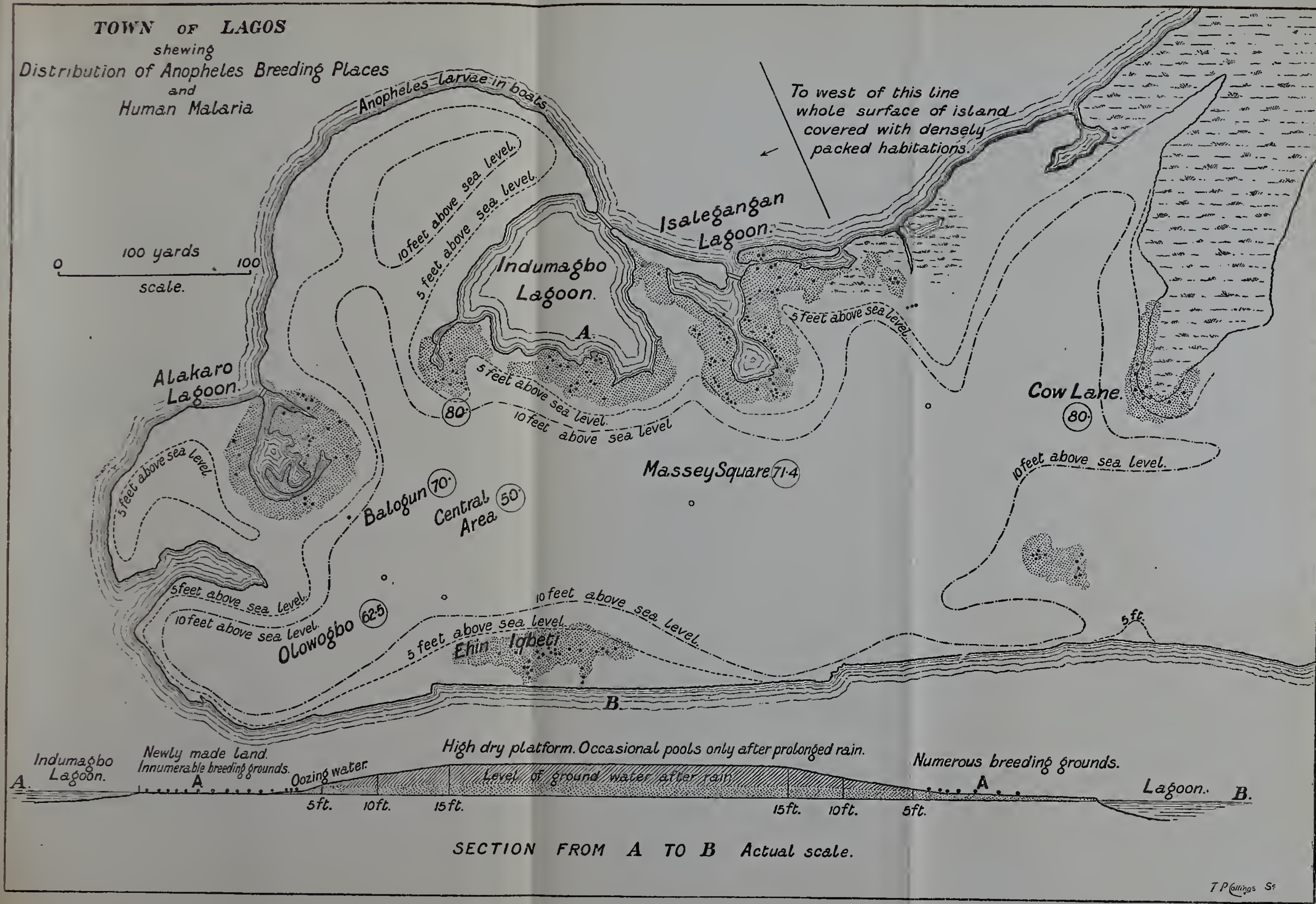
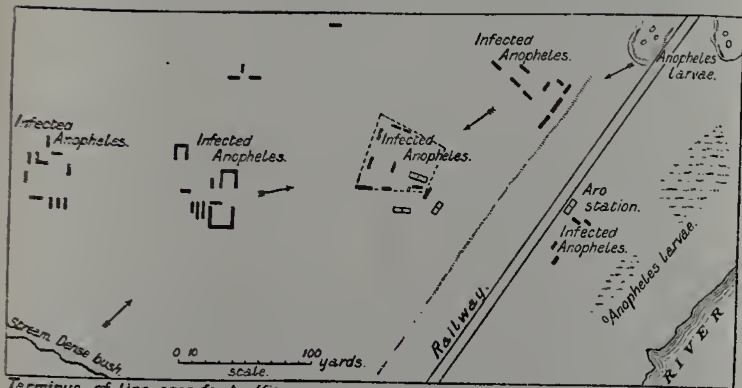

TOWN OF LAGOS
shewing
Distribution of Anopheles Breeding Places
and
Human Malaria
Anopheles Larvae in boats
To west of this line whole surface of island covered with densely packed habitations.
0 100 yards 100
scale.
10 feet above sea level.
5 feet above sea level.
Indumagbo Lagoon.
Isalegangan Lagoon.
A.
Alakaro Lagoon.
80
5 feet above sea level.
10 feet above sea level
Cow Lane.
80
Massey Square 71·4
Balogun 70
Central Area 50
10 feet above sea level.
5feet above sea level.
10 feet above sea level.
Olowogbo 62·5
5 feet above sea level.
Ehin Iqbeti
5ft.
B.
Indumagbo Lagoon.
Newly made land. Innumerable breeding grounds.
Oozing water.
High dry platform. Occasional pools only after prolonged rain.
Level of ground water after rain.
Numerous breeding grounds.
A. A A B.
Lagoon.
5ft. 10ft. 15ft. 15ft. 10ft. 5ft.
SECTION FROM A TO B Actual scale.
T P Collings Sc

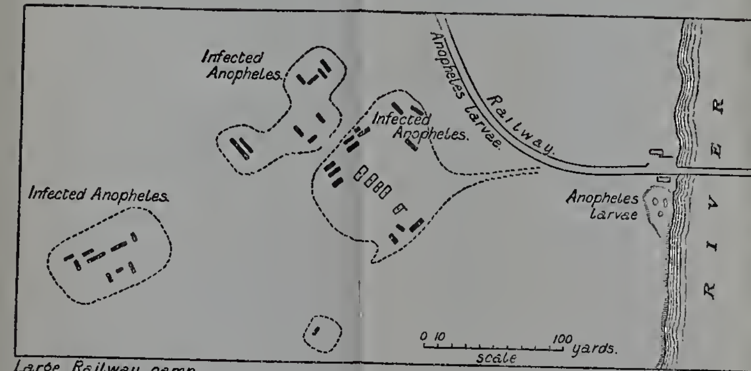
PLATE 3.

PLAN I.



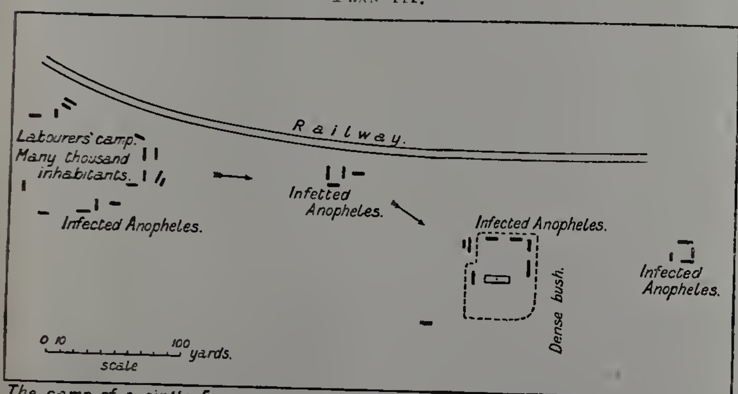
Terminus of line open for traffic.
European quarters ▭.
Native huts and compounds ▮ ⊓.
The arrows indicate spread of Anopheles.

PLAN II.



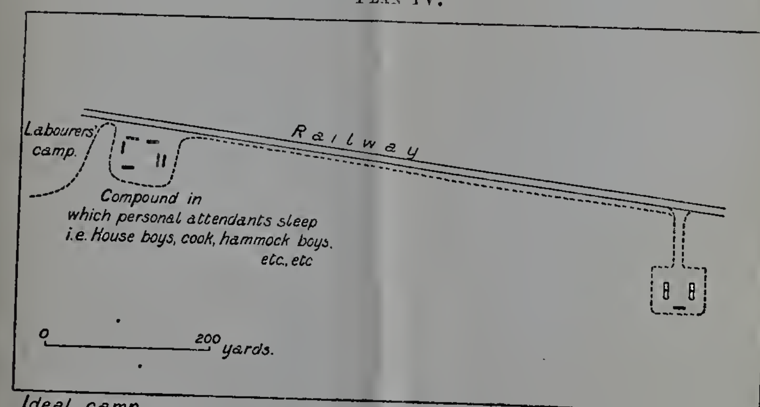
Large Railway camp
European quarters ▭
Native quarters ▬

PLAN III.



The camp of a single European at rail-head.
European's quarters ▭.
Native huts ▬
The arrows indicate probable spread of Anopheles.

PLAN IV.



Ideal camp
Europeans. ▭
Natives ▬

To illustrate Note on Malarial Fever on Railways under Construction.

REPORTS, &c., FROM Dr. C. W. DANIELS, EAST AFRICA.

Covering Letter.

Fern Lea, Mossley Hill,
Near Liverpool,
October 21, 1900.

Sir,

I have the honour to forward herewith a final series of reports on the distribution of Anopheles and the Prophylaxis of Malaria.

2. I hope in a short time to forward also some notes on "Blackwater Fever" in that Protectorate.

3. Prophylaxis has been considered exclusively with regard to Europeans. Little could be done in this respect for the natives at present.

4. Specimens of the mosquitoes have been forwarded to the British Museum.

I have the honour to be, Sir,
Your obedient servant,
C. W. Daniels.

The Secretary,
The Malaria Investigation Committee,
The Royal Society.

Distribution of Anopheles in the Lower Shire, Zambesi, and Chinde Rivers.

These observations were made from Chickwawa, at intervals down the rivers mentioned, to the coast, a distance given as 300 miles.

Observations had been previously made at Chickwawa, in October, 1899, late in the dry season; and in February, 1900, late in the wet season.

In other places no observations of much value had been made, as when I went up the river, I did not know the usual breeding grounds.

The observations at Chickwawa differ little from those made

previously. Abundant anopheles larvæ were found in the grass growing in shallows at the edge of the river and in grass-grown sandbanks well out in the stream. They were not found elsewhere. The river was about 2 feet lower than in February; but areas grass-grown and partially submerged were still very extensive.

In the houses culices were much rarer than on previous occasions, but anopheles were very numerous.

It is probable that there was an increase in their numbers as compared with previous occasions.

A native with filaria was persuaded to sleep under a looped-up mosquito net on two nights. In the mornings the mosquitoes found were 100 and 94 anopheles and 6 and 2 culices. In similar experiments made in October and February, 30 to 40 anopheles were found and 60 to 80 culices.

Whether this greater prevalence, absolute as well as relative, indicates that the lower temperature 60–85, at this season of the year, is more favourable to this mosquito than the higher temperatures 85–105 at my previous visits; or that the diminished strength of the stream is the cause of the increase I could not determine, but incline to the former hypothesis.

The Shire river is dependent, for its constant flow, on Lake Nyassa. The permanent streams running into it are few and small, and during the dry season probably insufficient to do more than replace evaporation and absorption.

During the wet season these streams are larger and there are numerous additional streams. The slope from the watershed is steep so that floods are common. These are more important further down the river than Chickwawa.

The next observations were made at Chiromo, about 70 miles down the stream. This station is at the junction of the Ruo, the largest tributary, with the Shire. The banks of both rivers are steep and in the main clean-cut, but in some places at the base of the banks are patches of grass growing into these streams. In the patches anopheles larvæ of at least three species were abundant.

About a quarter of a mile higher up the Shire is a diverticulum of that river ending blindly in a marsh. In this diverticulum, called a lagoon, anopheles larvæ were readily found.

When in flood the Shire pours into this lagoon and floods an extensive area. This area would undoubtedly form an extensive breeding ground during the wet season, as it would form a marsh, well supplied with fresh water at that season. It is immediately behind the township. The "lagoon" itself is of less importance as it is on the leeward side of the settlement and over a quarter of a mile from the greater part of it.

The character of the banks of the Shire varies. In no part of the

lower river are they rocky, but alternate between clean-cut earth banks and more sloping banks with extensive grass-grown areas or grass-grown shoals.

Observations made on the mosquitoes on board the boat 40 miles from Chiromo showed abundance of the small black* anopheles, and amongst some mosquitoes collected for me by Surgeon Gilmour, R.N., of Her Majesty's gunboat "Herald," both these and another anopheles with white barred legs (also found at the north end of Lake Nyassa, Chickwawa, and Chiromo)† were found. These mosquitoes were collected at the junction of the Shire and Zambesi rivers.

Some 50 miles below this point in the Zambesi is the old point of departure for Quilimane, Vicente. Here I spent two days.

In the early days the Zambesi had here a mouth opening at Quilimane, and in flood time the communication has been reopened.

The banks here are steep and clean-cut, as now the main channel of the Zambesi is encroaching on them. We tied up against this bank for the night; no anopheles were found.

About 3 miles inland is a large sugar plantation, Mopea. Through this plantation runs the Kwa Kwa, a narrow stream, the representative of the old Quilimane mouth. This stream is extensively grass-grown and in places nearly covered with aquatic plants (lilies); anopheles larvæ were plentiful.

From this stream is a large back-water, in part artificial, running close to the sugar mills, and used as a source of the water required for the mill. In this back-water and an adjoining pool anopheles larvæ were very abundant.

On the plantation are two large ponds, one of them 1½ miles in length. The water in these is quite fresh and there is much grass growing at the edges into the shallow parts as well as floating masses of aquatic plants; in these situations anopheles larvæ were found.

The water used in the houses is rain water, collected in iron tanks; in none of these did I find anopheles larvæ.

Irrigation is being resorted to for the cane fields and will be more extensively so. The irrigation is of two kinds. In the first, by means of steam pumps water is pumped into trenches from the Kwa Kwa or lakes. The trenches are blocked at certain points and the water is pumped in till the areas fed by these trenches are supplied. By this method the water does not stand very long on the land and the supply is intermittent. No anopheles larvæ found here.

In the second method the waste water from the mill is poured into one of the main trenches and an extensive area is thus partially irrigated. Towards the limit of the area supplied anopheles larvæ are abundant.

* *Anopheles funestus.*

† *Anopheles costalis.*

Here the water supply is continuous but not sufficient for the area to be irrigated, and is another instance of the danger of an irrigation system too extensive for its water supply.

A few years ago this plantation was considered to be very unhealthy but is now not so thought of, as there is very little invaliding, and deaths amongst Europeans are rare.

The following particulars, kindly supplied to me by Dr. Cruikshank, the medical officer of the plantation, show the first occurrence of fever amongst the new-comers during the sixteen months he has been there :—

	Fever under 1 month.	Under 3 months.	In 4th month.	In 7th month.	No fever.
4 have been 16 months	2	1	1	0	
2 „ „ 15 „	1	0	0	1	
6 „ „ $2\frac{1}{2}$ „	3	1	0	0	2
3 „ „ $1\frac{1}{2}$ „	2	0	0	0	1
15	8	2	1	1	3

Thus: Of 15, 8 had fever under 1 month, 2 under 3 months, and of the remaining 5—2 had fever in the 4th and 7th month, and 3 have not yet been resident 3 months.

During this sixteen months there have been four cases of blackwater fever out of a European population reaching forty in the busy season, but much less during the rest of the year.

The morbidity, therefore, is well above the average for British Central Africa. The general appearance of good health, the absence of mortality during the period, and the small number invalided (2), are to be attributed to the regular life on a sugar estate and the attention devoted to the provision of good and varied food, rather than to the natural healthiness of the locality. Quinine, 5 grains, is taken regularly daily by almost all, and some take 10 grains.

The natural breeding grounds of the anopheles on this plantation are so extensive that they could not be dealt with economically, and the prophylaxis would have to be limited to better protection against the mosquitoes.

Anopheles, small black, were also found at night in numbers, about 20 miles further down the Zambesi, at the junction of Chinde and Zambesi rivers, 32 miles from the mouth, and again about 10 miles from the sea up the Chinde river.

As we pass towards the mouth of the river there are two additional actors to be considered :—

(1.) *The Tide.*—At the time of year, July, the river is tidal for about 50 miles, and considerable portions of the bank are left bare when the tide is out.

With low sloping grass-grown banks small pools will be left in which the larvæ could be secure till the next tide. The rise and fall of the tide insures the removal of decomposing vegetation and the purity of the water for a considerable distance amongst the grass on the shallows.

The influence of the tide does not seem to be disadvantageous, as the mosquitoes were abundant 10 miles from the sea.

(2.) *Admixture with Salt (Sea) Water.*—The water, even in the dry season, was quite fresh about 8 miles from the sea. Below this, grass is found in the river in smaller and smaller quantities and is replaced by mangrove swamps completely for the last 2 or 3 miles.

At Chinde I failed to find any anopheles larvæ in the mangrove swamps, in the salt pools above the creeks, or in salt and brackish puddles above high-water mark.

The soil is sandy, and though there were frequent light showers there were no puddles in the sand.

Fresh water is obtained from wells—either European or native. In none of those examined were anopheles larvæ found, and the level of the water was 4 to 8 feet below the surface of the soil. In similar wells elsewhere I have failed to find these larvæ.

There are also a large number of iron tanks filled by rain water from roofs, and water is also collected from the same source in wooden barrels. In many of these there were numerous culex larvæ, but in none did I find anopheles.

On the coast there are frequent showers even during the dry season, though the rainfall is not heavy. The air also is moist. Water will remain for considerable periods in open vessels, the small loss from evaporation being replaced by the rainfall. In one wooden tub I found larvæ of two species of anopheles, but not of the small black anopheles.

I examined many rooms and beds for adult mosquitoes, and found a few anopheles, of a species fairly common, on the lower river, one very large anopheles which I failed to secure and therefore cannot identify, and one, and one only, of the "small black" anopheles. This solitary specimen does not, I consider, conclusively establish the presence of this species of anopheles at Chinde under natural conditions, as the house in which it was found was close to the part of the river bank where steamers are often moored, and, as has been shown, this mosquito is abundant a few miles up the river.

Though at this time of year I found no situations which I thought were suitable for the growth of this mosquito, it is probable that in the more rainy months suitable places do exist. The grass in some of the hollows is of the character I associate with fairly permanent fresh water.

The native gardens are often in such hollows, and I am informed that in the trenches between the rows water often remains for considerable periods.

When the Zambesi is of much greater volume, as it is during the rains, the water is fresh quite close to Chinde, and therefore there will be breeding grounds of the small anopheles much closer to the township, and perhaps larvæ washed down may find a resting place in the creeks.

I have had no opportunity of making observations on the effect of the rainy season at Chinde. Chinde now has the reputation of being a healthy place for residents, though formerly there was much sickness and death amongst residents from the Highlands, &c., on coming down there. Probably this only indicated the maturation of infections acquired in the Upper or Lower Shire rivers.

It will be seen from the above that the "small black" anopheles, in which I have shown crescents develop, is met with in the Highlands on each side of Lake Nyassa and in the whole length of the water system from the north end of Lake Nyassa down the Upper, Middle, and Lower Shire rivers and in their tributaries, down the Zambesi river and its Chinde mouth near to the sea; this is a distance of some 850 miles. I have identified the same mosquito amongst specimens sent me by Dr. Mackae from the south end of Tanganika, so that it has a minimum range extending from a point 18°·50 S. by 36°·50 E. to 9° S. and 31° E.

The mosquito has been identified by persons living on the Tanganika plateau, on the Zambesi and Congo watersheds, and as far up the Zambesi as the Lupata gorge; above that point the river runs through rocky channels, and there are said to be few mosquitoes.

This actual area, though large, is not likely to be the limit of the range of this mosquito, as similar physical conditions prevail over a much larger area, and would include the higher reaches of the Congo and Nile as well as of the Zambesi and the smaller rivers running to the east coast, and also the other fresh-water lakes. The other anopheles are rarely in any number, none of them have as extensive a range or are found under as varied conditions. Whether they can carry any form of malarial parasite has not been determined, but their importance is small compared to that of the other.

Their breeding grounds are similar, often the same.

Distribution of Anopheles Breeding Grounds in the British East African Protectorate. (Uganda Railway.) August, 1900.

The places examined were the island of Mombasa and various points on the Uganda Railway for a distance of 326 miles, and up to an elevation of 5600 feet. The general line was from about 4° S. and 39°·40 E. to 1° S. and 36°·50 E.

The island of Mombasa is of coral formation, and about $3\frac{1}{2}$ miles long by $1\frac{3}{4}$ miles broad. There is no running water, and fresh water is obtained from deep wells and from rain water stored in tanks. In neither of these situations were anopheles larvæ found. Towards the centre of the island there is a depression, and in this water collects.

The shallow pool thus formed contains water in most years constantly, but has been known to dry up in exceptionally dry years.

The pool has shallow edges, and for a great extent is covered with short grass, rushes, and water lilies, but in the centre is quite clear. In no part is the water putrid, peaty, or markedly stagnant.

In this pool anopheles larvæ were found in fair numbers, apparently of three species, including the "small black" anopheles. This was the only place on the island in which I found anopheles larvæ, and I neither found, nor could I hear of, any other natural open fresh water.

The water at selected places on the line was examined. At the more important places which Dr. Sieveking, the principal medical officer of the Uganda Railway, had indicated, I made a stay of some hours; at the less important only short periods. For about 20 miles from the coast rains fall irregularly during the greater part of the year, and at the time of my visit this stretch of the country was green, and pools were present in suitable places. Such places are common, as in making the railway embankments numerous shallow pits are made. These are called "borrow pits," and for convenience in the estimation of work done are made square and of uniform depth, and partitions are left between the pits made by different gangs or contractors. The result is the formation of an infinite series of potential pools all along the railway.

In the first 30 miles of the railway many of these "borrow pits" contained water, and in some of them anopheles larvæ were present in numbers.

Beyond this the pits were dry, but obviously in a wet season might be fruitful subsidiary sources of these mosquitoes.

For the rest of the line the places examined may be considered in the main as permanent breeding grounds, as the water comes from

the higher mountain ranges, including snow-covered mountains, Kilimanjaro, 19,300 feet, and Kenia, 18,620 feet.

In the following list the number of miles is the distance from the coast terminus of the railway, and the second number is the height in feet above sea-level.

Mazeras. 14 miles, 500 feet. Anopheles larvæ in stream and "borrow pits."

Majichumvi. 27 miles, 650 feet. Slowly running stream. *No anopheles larvæ found.* Subsequent inquiries showed that this stream contained much salt. One analysis gave 204 grains of solids in solution per gallon, and 152 of this was sodium chloride. In some "borrow pits" near, larvæ were found (anopheles).

Somburu. 41 miles, 1000 feet. Large pools in granite rock; in some of these anopheles larvæ were found. These pools dry up in prolonged rainless periods, but such are not common so near the coast.

Voi. 100 miles, 1800 feet. River with grass-grown edges. Very numerous anopheles larvæ. On each side of the river is a marsh: in the stagnant pools in it no anopheles larvæ, but only culex larvæ, were found. In a rainy season this marsh is said to be flooded by the river, and then would probably be suitable for the growth of anopheles larvæ, so that these marshes may be a subsidiary or potential breeding ground. "Borrow pits" near railway; dry.

Mtoto. 160 miles, 2500 feet. Stream running in channels over granite rocks in places spreads out and is partially grass-grown. Numerous anopheles larvæ, all of the "small black," were found. No other mosquito larvæ were found.

Masongloni. 182 miles, 2800 feet. Stream much overgrown with grass and abundant algæ. Slowly running. Some anopheles larvæ were found, but those of culices much more abundant.

Kibwezi. 193 miles, 3000 feet. An underground river, running through lava, appears on the surface on the south side of the line as a series of pools, and on the north as a clear running stream. Anopheles larvæ were exceptionally abundant in both situations at any place where there was any obstruction.

Makindo. 207 miles, 3250 feet. A river forms a loop round the settlement about 1½ miles from it. In the grass-grown edges of this stream there were numerous anopheles larvæ. "Borrow pits" are here abundant, but as there had been no rain were all dry.

Kiu. 265 miles, 5200 feet. The stream was in great part dry, but there were some water holes in which the water appeared to be fresh. Anopheles larvæ were found in them.

Nairobi. 326 miles, 5600 feet. The river is much grass-grown and anopheles larvæ were abundant. In pools, in a surrounding marshy area, anopheles larvæ were found, but only in a small proportion of them. The country here is better watered, and though the river was low slight rains are common and the air is moist.

At some distance from the river is a marshy area, through which a small stream runs. In this stream wherever there was any obstruction anopheles larvæ (two kinds) were found.

In a drainage trench from this marsh, in a badly-graded portion, water had collected, and in it anopheles larvæ were found.

The larvæ at this place, the greatest height I reached (5600 feet), were fairly abundant, though perhaps not as much so as they would have been in similar situations in the Shiré Highlands at 3200 feet. They should, I think, be found, though perhaps only in small numbers, for at least another 1000 feet.

On the whole, British East Africa appears to be healthier than British Central Africa. The country (British East Africa) is not so well watered and the undulations are further apart, whilst the permanent settlements are in most cases not so near permanent water.

The temporary or subsidiary breeding grounds are more numerous, as owing to the absence of the tall rank grasses of British Central Africa, water which there would form putrid marshes here forms open pools.

There is a close general correspondence between the reputed unhealthiness of the places examined and the extent and proximity of anopheles breeding grounds, actual or potential.

The anopheles found include in all cases the "small black"; two of the other species occur in British Central Africa, and other larvæ were found which failed to hatch.

Geographical Distribution of Anopheles in Africa.

Several species of anopheles are found in British Central and British East Africa.

The most important is the one I have usually called the "small black" anopheles, which appears to be *Anopheles funestus.*

This species has been shown to carry malaria (crescents). It is the most numerous, the most widely distributed, and the most persistent frequenter of houses.

In one district, and that the most malarious, it is the only anopheles found, and is more numerous than any of the culices there present. These culices have been proved not to carry malaria.

I have found this anopheles at points in the whole course of my journeys, extending over some 1500 miles. Near the equator, rather more than 1° S., it was found in fair numbers in the cool season 5600 feet above sea level. Further south, 15°, it was found, but in very small numbers, at an elevation of 5000 feet, but is common there at 3000 feet. I have found it in numbers at sea level, from 1° to 18° S. These are the limits of my observations.

This indicates a very wide distribution much more extensive than that actually observed. It thrives under climatic conditions where European vegetables are grown, as well as where the vegetation and products are purely tropical.

The accompanying Map and Sections A and B (pp. 36–37) give representations of the raised central portion of Africa, which forms the watershed between the main rivers on the east coast, including the Zambesi, the Nile on the north, and the Congo on the west. The portion underlined with dots indicates the main route I have traversed and found this anopheles; whilst the crosses indicate points which I have not visited, but at which I have proof of the existence of this mosquito.

As the climatic and meteorological conditions in the intervening but unvisited portion (marked with solid line only) are similar, it can be fairly assumed, at corresponding and lower heights in this portion also, the same anopheles occurs.

The probable limits of the distribution of this anopheles can, at present, only be inferred. The rainless portion of North Africa would be unsuitable to their life. The connecting waterway, the Nile, with its barren banks and cataracts, would afford little shelter for larvæ, so that it is improbable that the mosquito exists for any great distance beyond the well-watered portion.

To the South frosts occur. I have no experience of that condition in this connection. If prolonged frosts form the southern limit of the distribution of this anopheles, this limit would be indicated by an irregular broken line convex to the north on account of the elevated character of the interior.

The actual coast line is comparatively free from this anopheles, as the river water there is brackish for a great part of the year. The more uniform distribution of the rains and the higher level of the subsoil water favour the formation of pools, and therefore the subsidiary breeding grounds are more permanent and of greater importance than in the highlands in the interior.

The other anopheles are of more limited distribution, but some of them are found at places far apart. Of these the *Anopheles costalis* is of the most importance, as it seems to be the chief agent on the West Coast of Africa. This anopheles is found on the Zambesi and Lower Shire rivers, and in the northern part of Lake Nyassa, but I have failed to find it in the Shire Highlands and Upper Shire rivers. On

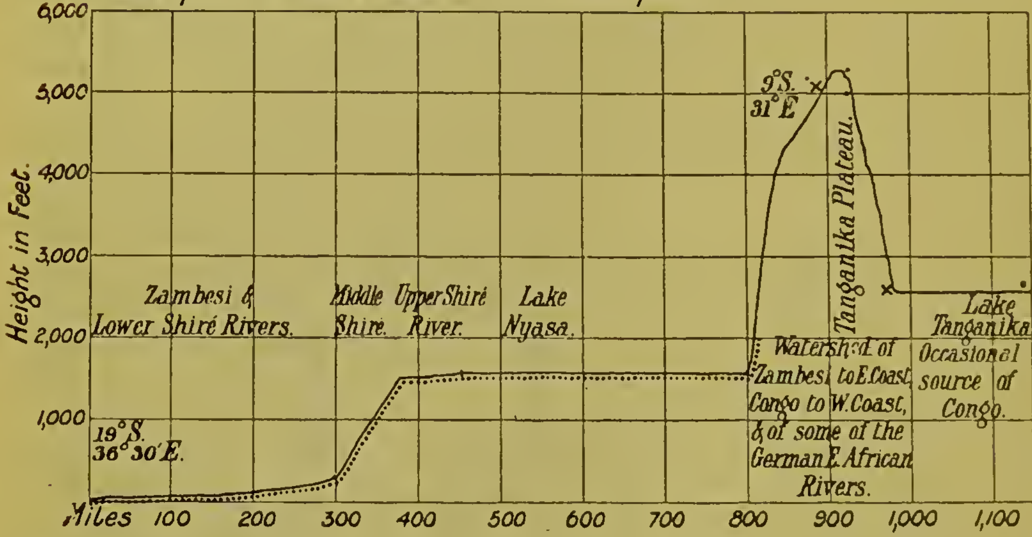
A ——— A } *Two routes through which the sections*
B ——— B } *A & B are taken.*

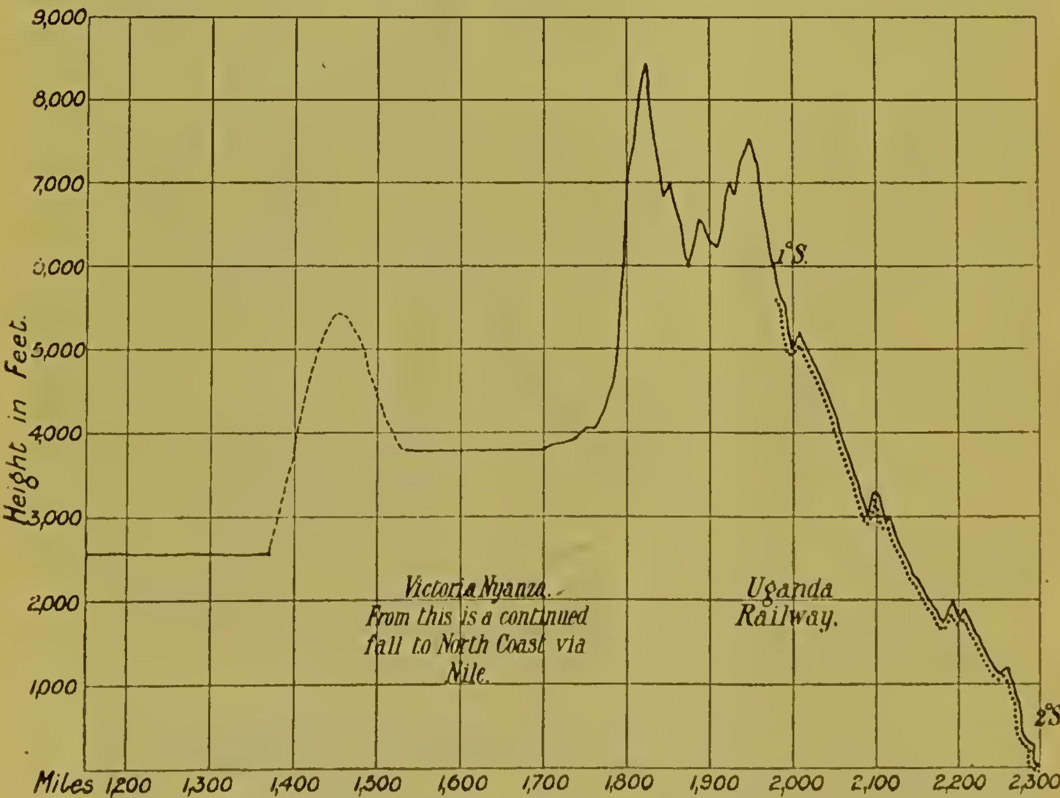
Portions of the routes in which the Mosquitoes have been determined

the Uganda Railway it was found in places up to a height of 3000 feet.

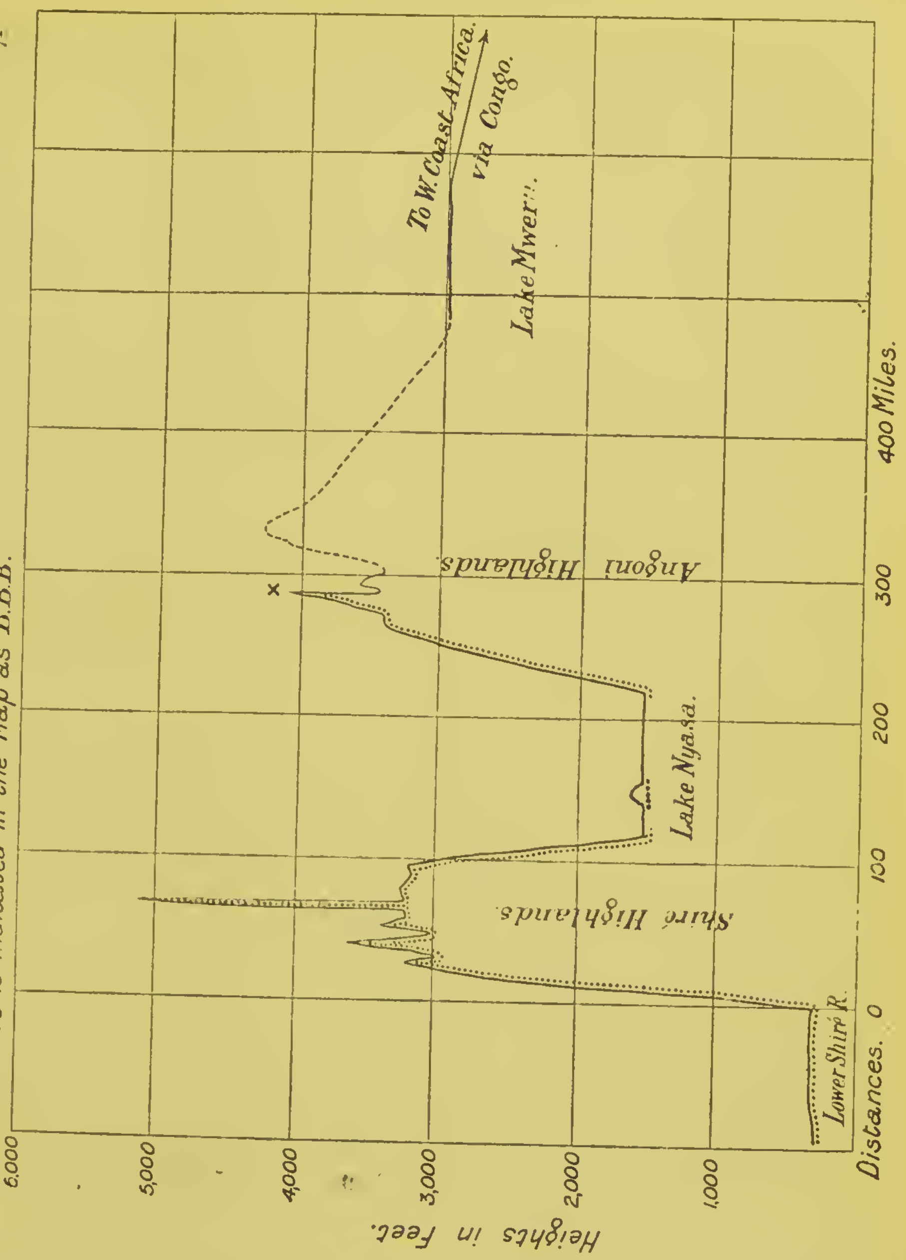
This mosquito is not found so plentifully in houses as the *Anopheles funestus* even where, as at the north end of Lake Nyassa, the larvæ are abundant, nor does it remain in the house in the same way.

A. Representation of section through Central Africa along the route marked A.A.A. in the accompanying Map. (Map I). The portion underlined thus .... indicates the part of the route I have traversed. All along this portion Anopheles funestus was found. The crosses indicate other points at which I have proof of the existence of the mosquito.





The larvæ are often found with those of *Anopheles funestus*, but it is also found alone in more stagnant water. It was one of the mosquitoes found in a tub on the sea coast, Chinde, at the mouth of the Zambesi.



B. Oblique section from the Lower Shiré River, across the Shiré Highlands, Lake Nyasa, the Angoni Highlands to Lake Mweru. The portion underlined thus .... indicates the portion of the route traversed along which Anopheles funestus was found. This route is indicated in the Map as B.B.B.

In some places this mosquito may be of importance, but as regards the interior it can be only of minor importance as compared with the *Anopheles funestus*.

Prophylaxis.

The evidence in British Central Africa, as elsewhere, shows that malaria is propagated by anopheles. The anopheles of most importance is the *Anopheles funestus*, as it is more prevalent and more numerous than any of the others.

There is no evidence that the parasites in the mosquito are derived from any source but man, and all the facts observed are explicable on the hypothesis that man is the sole intermediate host.

On these two points the whole question of prophylaxis depends.

A consideration of the diverse breeding grounds of the anopheles larvæ in Africa will show that whilst it is impracticable to exterminate this mosquito, yet in certain localities the number of them could be greatly reduced.

There are two classes of breeding grounds—*permanent* and *subsidiary*.

The permanent breeding grounds include springs, streams, rivers (especially when grass-grown), permanent pools, and sheltered portions of fresh-water lakes. Such places could not be dealt with by the use of kerosine or other larvicide.

Springs, in proximity to European quarters, could be drained by making wells. Streams can be cleared and kept free from obstructions. Sites on river banks avoided in places where grass-growth in the river bed is great, and where small patches only exist these could be destroyed.

So far some of the evils have been increased by artificial means. Such obstructions as dams, drifts, or stone crossings, and the deposition of brushwood or trunks of trees parallel to each other in the course of a stream, "corduroying" the bed, are particularly dangerous. Grass and other refuse from clearing the ground is often thrown into the streams, and forms an obstruction.

The *subsidiary breeding grounds* are either natural or artificial. The *natural* ones are hollows where rain water can collect; marshes, small or large, when either well supplied with fresh water or covered only with shorter grasses or rushes; pools formed by filtration from a neighbouring mass of water at a higher level.

Some of these places might be dealt with by kerosine or other larvicides. In others, extensive drainage and often embanking would be requisite. Such places should be avoided.

The *artificial* subsidiary breeding grounds are of great importance. They include irrigation systems with too limited a supply of water; badly-graded trenches; leaky trenches, and trenches overgrown with grass or otherwise obstructed. These faults should be avoided. In a well-designed irrigation system kept clear, anopheles larvæ are rarely found, unless these larvæ are present in the source of the water.

Trenches between rows such as are often made in native gardens are dangerous, with a high level subsoil water. As these gardens are made at the edges of marshes and in old river beds, in some situations, suitable collections of water readily form.

Rice fields when flooded are suitable places.

I am informed that in Russian Central Asia native gardens and rice fields are not allowed to be made within a certain distance of European

settlements, and that since this prohibition was enforced there has been a marked diminution in the malaria.

Excavations when deep, as the brick pits and native wells are in British Central Africa, do not seem to be the habitat of anopheles larvæ. Shallow pits are of more importance, but only when there is a steady rainfall or the level of the subsoil water is high. The pits made by removing earth to form railway embankments, "borrow pits," frequently contain anopheles larvæ.

These excavations are subdivided by partitions, as the work done is estimated for each gang by the amount of earth removed. A continuous excavation would be less dangerous as it would be flushed by heavy rains, and, except on level ground, would hold less water.

Distribution, as larvæ, of the anopheles takes place to some extent. The common occurrence of the larvæ in springs and at the edges of rivers enables this process to readily take place. The larvæ do not probably travel far by their own exertions, but, if swept into a stream, especially if amongst detached masses of grass, they could be carried down for indefinite distances. It is very doubtful if they would survive a passage through any extensive rapids. This indicates a danger of the possibility of these mosquitoes spreading down rivers to districts free from them, and should be considered when undertaking any extensive works in connection with rivers.

Any attempts, even in small areas, to diminish the amount of malaria by attacking the anopheles breeding grounds will be attended with some expense, and will be useless unless constant, individual and corporate, care and attention are exercised. There is no excuse for the multiplication of breeding-grounds and little justification for the optimistic view that, even without special attention, malaria will diminish as a result of European occupation. The effect of this occupation in British Central and British East Africa, so far, I consider to have resulted in an increase in the area and number of the anopheles breeding grounds in many places.

Receptacles such as tanks, barrels, &c., do not seem to be suitable breeding grounds. Shallower receptacles occasionally harbour them, as Dr. Howard found larvæ in a disused canoe, and I have found them, but not *Anopheles funestus*, in an open tub. Such receptacles it is well to have overturned.

Protection from Mosquitoes.—The main reliance in many places must be placed on protection from the bites of mosquitoes. The more efficient this protection the better, but any increase in it will be beneficial proportionately.

Mosquito-proof houses, if properly used, would be the most effective. The care required is great, and any mosquitoes obtaining an entrance would have little opportunity for escape. The *Anopheles funestus* enters houses to some extent in the daytime, so the houses must be kept per-

manently closed. Fumigation as an additional precaution would reduce these difficulties. Extensive alterations in existing houses would be required to render them mosquito proof. Wire gauze greatly checks the passage of air. To be equally cool a much larger area for ventilation would be required than the present door and window space. They would be too expensive for many people. In African houses it is essential that little woodwork be used as it is rapidly destroyed by ants.

On the whole, I consider that small low rooms of mosquito-proof gauze (wire) in thoroughly well-ventilated houses would be more convenient, cheaper, and more likely to be generally adopted. They can be thoroughly inspected and seen to be free from mosquitoes.

In the absence of mosquito-proof rooms mosquito nets should be used, even when no mosquitoes are noticed.

Many of the nets in use are faulty. The meshes are too coarse as the small mosquitoes, and particularly the important one *Anopheles funestus*, can pass through. Muslin nets are efficient, but close and hot. Something intermediate is required. Nets should be fixed inside the frame of the bedstead. If outside it is difficult to tuck under the mattresses at the corners.

Some nets are tent-shaped. These are suspended from small circular frames hanging from the roof. In such the net is so low at the ends of the bed as often to be in contact with the person's extremities. Narrow "camp" bedsteads are much used on account of their portability. In these some portion of the person is usually in contact with the net. Mosquitoes gorged with blood are often found on the outside of the net.

Some nets have a slit from top to bottom. These require such careful adjustment that they should be avoided, as unless carefully adjusted, mosquitoes obtain entrance through the slit.

Other nets are not tucked in at all, but are weighted along the edges and rest on the ground. Numerous mosquitoes are found in such nets.

The best form, I think, is the ordinary oblong net, fixed to the inside of posts at the corners of the bed, and carefully tucked in all round.

In badly-managed houses it is not unusual for the net to be simply thrown over the top of the bedstead in the daytime, and contained mosquitoes are thus retained. When the net is put down at night these mosquitoes are set free in the net and can again attack the occupant.

Clothing gives some protection. The feet and ankles are the parts most usually attacked ; high boots, leggings, or what most people will prefer, double socks, give a fair amount of protection, and so does the frequent use of various essential oils.

Much of the malaria in the Highlands of British Central Africa is acquired whilst travelling on steamers to them. On the Zambesi and Lower Shire rivers anopheles abound, and in narrow bunks with short mosquito nets there is little protection.

The time spent on this journey in actual travelling has been materially reduced in the course of the last year by the competition of various companies. There is room for further improvement, particularly in making connection where transhipment is required.

This matter is largely in the hands of missions and companies, as a time-limit for the journey should be insisted on in the contracts with transporting companies.

There should be no insuperable difficulty in making cabins and saloons mosquito proof.

It would be better, when it is impossible to travel by night, to anchor out in the stream instead of being tied up to the bank, as is now usually done. There is no need at all to tie up in the proximity of a native village.

Daily fumigation of all cabins should be done towards sunset.*

The proportion of *Anopheles funestus* infected with malarial parasites in British Central Africa seems to be small.

Exclusive of mosquitoes reared from larvæ, I examined over 1500 without finding one with a zygote. These mosquitoes were caught in European houses and kept till they had digested at least one meal of blood.

The clinical evidence points to the same conclusion, or rather to the conclusion that an infective swarm of mosquitoes is only occasionally met with.

Every person coming up to the Highlands must be bitten under present circumstances by hundreds of anopheles during the two weeks or so spent on the Zambesi and Lower Shire rivers, and yet 75 per cent. appear to escape infection. In some journeys every person gets fever; in others none.

On Her Majesty's gunboats there is a decided tendency, judging from the returns kindly supplied to me by Surgeons Vaudin and Gilmour, R.N., for the cases to occur in groups, showing that there

* For commercial purposes a railway from Chiromo to Lake Nyassa has been strongly advocated.

Such a railway would be most beneficial to the public health, as by it access would be obtained to the Shire Highlands and the lake shore without a single night being spent in the two worst portions of the country, namely, the upper reaches of the Lower Shire and the Upper Shire river.

Residents on these portions of the river are mainly stationed there in connection with transport work; and, if the railway were made, the number of European residents in those places would be reduced: a large decrease in the amount of malaria would certainly result, and probably a decrease in the amount of "Black-water Fever."

are periods when no infections take place. These periods in several instances were over a month.

The paucity of infected mosquitoes I attribute to the small number of cases in which crescents are found in large numbers. Out of 220 mosquitoes (*Anopheles funestus*) fed on patients in whose blood one crescent was found after repeated examinations, none developed zygotes.

These poor crescent cases seem to be the rule alike in Europeans, natives (both adults and children), and Indians in British Central Africa.

There can be no doubt that the natives are the common source of the parasites. It is no new discovery that children in malarial countries are not only not immune but are almost all attacked by fever. In British Guiana, a moderately malarial country, this prevalence of malaria has been long known clinically.

Out of 1289 unselected post-mortem examinations on persons, natives of British Guiana or coming from other malarious countries, microscopical examination of the spleens showed malarial pigment as follows:—

Under 1 month	Nil.
,, 6 months	25· per cent.
,, 1 year..................	21·4 ,,
,, 2 years	54·5 ,,
From 2 to 5 years.........	81·4 ,,
,, 5 ,, 10 ,, ...	67·5 ,,
,, 10 ,, 15 ,, ...	77· ,,
,, 15 ,, 20 ,, ...	52·3 ,,
,, 20 ,, 25 ,, ...	37·9 ,,
,, 25 ,, 30 ,, ...	30·3 ,,
,, 30 ,, 35 ,, ...	17·9 ,,
,, 35 ,, 40 ,, ...	14·1 ,,
,, 40 ,, 50 ,, ...	13·2 ,,
,, 50 ,, 60 ,, ...	11·1 ,,
,, 60 and over............	11·6 ,,

and I further pointed out that over twenty the pigment was "very rarely recent." ('British Guiana Medical Annual,' 1895, 57–61.)

That the same is the case in British Central Africa is shown both by the prevalence of malaria, verified by blood examination in the children, and by the fact already reported that children free from manifestations of malaria in several instances have parasites. The age-incidence of enlarged spleens as reported from time to time confirms this view. Professor Koch has demonstrated more directly elsewhere the enormous preponderance of the infections in children.

As therefore the native population is a constant source of danger, it is not advisable that European settlements should be near native settlements. In Russian Central Asia, none are allowed within a certain limit. In British Central Africa, even where native houses are not allowed in the portion allotted to Europeans, they are allowed close to and often surrounding it. No order, cleanliness, or spacing is insisted on, and the houses are placed as close together as the people like. In missions, the school children are often resident on the mission grounds and must be a source of some danger.

It must always be remembered that in a European, convalescent from an attack of fever, his parasites will be in the stage capable of being transmitted to the mosquito, and he must be well guarded against the attacks of mosquitoes, both for his own sake and his neighbours. With such an inmate thorough fumigation of the house should always be practised.

It is so commonly stated that alcoholism is a cause of the sickness and mortality in Africa, that I think it well to state here that it is not common in British Central Africa. Such cases as occur do not appear to suffer more from fever than others, whilst the sickness and deaths amongst abstainers, including missionaries, is so great as to show that abuse of alcoholic stimulants can have little to do with the matter. There are individual exceptions.

As good living as is procurable is of importance, not that it diminishes the susceptibility to malaria but that it enables more rapid recovery.

Sufficient attention is not paid to sanitation in its widest sense. Sanitary works are usually performed either by local boards or a general board of works, with or without medical advice. They are not directly under the control of a medical department. Money set apart to the medical departments is entirely absorbed in treating disease, *i.e.*, for hospitals, nurses, &c., and little or none spent in preventive medicine. Most of the money for public works is spent on public buildings and improvements which may be indirectly beneficial to the public health or not.

Money devoted to preventive medicine or sanitation should be kept apart from either the medical or public works votes, and accounted for separately.

A separate department for sanitary affairs distinct either from public works or the medical department would I think be advantageous in most places.

In conclusion I am of opinion that unless the amount of malaria can be materially reduced, colonisation by either Europeans or Asiatics cannot be successful in Tropical Africa.

There is also grave doubt whether even the negro population is increasing except in the more healthy districts. The climate is quite

suited for Europeans in the Highlands, and the country in part at least is fertile, but under present circumstances cannot be utilised, and any increase in the susceptible population without a corresponding decrease in the anopheles would probably lead to an increase in malarial diseases.

In the above I have limited myself to malarial infections from external sources. I have no doubt that exposure to sun, chills, over-exertion, and excess of all kinds in persons harbouring malarial parasites does bring on outbreaks of malarial fever. Such causes usually produce their effect speedily and not after a prolonged period of incubation. For prophylaxis avoidance of these causes is essential.

Notes.

Note on Occurrence of Anopheles in Madagascar.

In the course of the few hours spent at Nosi Bé I was able to examine streams of two kinds. In the one there was a series of water holes connected by a small running stream. Algæ were abundant. Anopheles larvæ and more abundant culex larvæ were found. In the other class the stream was clear and with little vegetation. Anopheles larvæ alone were found. The larvæ did not hatch on board ship, and I could not identify them, but they were not those of the "small black" anopheles. Two kinds were found.

Note on Occurrence of Anopheles in Zanzibar.

The country behind the town is gently undulating. In some of the hollows between the undulations there are extensive superficial pools. The grass at the edges is short, and beyond it are rushes and water lilies. Anopheles larvæ of two kinds were found, but, as with those at Nosi Bé, I failed to hatch them and could not identify them.

Such a situation in British Central Africa would have been covered with tall rank grass over 6 feet in height, and the water peaty and putrid.

Note on Food of Anopheles Larvæ.

The contents of the intestines of the larvæ are mainly vegetable matter, and in most cases entirely so. Occasionally limbs of minute insects or crustaceans are found as well as scales of mosquitoes or other insects.

On watching them feeding, it is seen that all minute particles are drawn to the mouth, but many of them are rejected. This rejection is somewhat arbitrary, as a particle at first rejected is often subsequently

swallowed. Amongst the bodies seen to be swallowed I have seen living minute crustaceans and young larvæ, both of anopheles and culices, but, as a rule, living animal bodies either escape or are rejected.

The feeding, with the young larvæ, seems to be entirely at the surface; but the more mature often descend in shallow water and feed at the bottom.

Note on the Supposed Opposition between Larvæ of Culex and Anopheles.

Either larvæ may be found alone, but in many situations both are found together, and often several species of each. At least five species of culex have been found with anopheles larvæ.

The less the movement of the water the greater the probability of culex larvæ being also found, and in a grass-grown river the anopheles larvæ will be more abundant near the stream and the culex larvæ near the bank.

Note on the Effect of Fish and Insect Larvæ in Destroying Anopheles Larvæ.

There is no doubt that, in confinement, fish, and especially young fry and small fishes, will speedily destroy the mosquito larvæ, but in spite of this, anopheles larvæ are often found in pools, rivers, &c., where fish are abundant, and pupa and mature larvæ amongst them. This is seen in open pools as well as in the grass-grown rivers.

Tadpoles do not attack the larvæ, even in captivity. Larvæ of Coleoptera and Dragon Flies are often found in numbers in water with abundant anopheles larvæ, and even in captivity do not seem to devour them.

Note on the Proximity of Anopheles Breeding Grounds to Human Habitations.

No relation has been observed in either British Central or British East Africa. Anopheles breed in permanent fresh water, and human habitations are also usually placed near such fresh water, but the larvæ are often found abundantly in suitable places which have not been selected by man also for habitation. Anopheles will feed on many animals besides man, so that even if mammalian blood is a necessity for their breeding, they have other opportunities of obtaining it.

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CONTENTS.

THE ANATOMY AND HISTOLOGY OF THE ADULT FEMALE MOSQUITO.

By S. R CHRISTOPHERS, M.B. Vict.

Received August 13, 1900.

[PLATES 1—6.]

The structure of the Mosquito has become of considerable importance since the discovery by Ross of the changes undergone by Proteosoma in a species of mosquito. Moreover, a knowledge of the structure of mosquitoes is necessary in following out not only the development of the parasites of bird and human malaria, but also of Filaria, and possibly of other disease-producing parasites.

We have therefore in the present article described more fully than has yet been done not only the gross anatomy, but also the minute structure, of the organs and tissues of Culex and Anopheles.

The Culicidæ are a highly-specialised group of Diptera. Their muscular, respiratory, vascular, and reproductive systems are to a large extent similar to those of other Diptera.

The genera of Culicidæ do not differ very much from one another in their general anatomy, and still less in the minute structure of their tissues. The differences between Culex and Anopheles, apart from external characters, are chiefly to be found in a generally more robust exoskeleton in Culex, and in the possession of sacculated salivary glands by Anopheles, whereas those of Culex are strictly tubular.

PART I.—THE GROSS ANATOMY.

The Exoskeleton.

As in most insects, the body consists of head, thorax, and abdomen. (Plate 1, fig. 1.)

The Head.—A large portion o the head is formed by the large compound eyes. These occupy the whole of the lateral portions of the head, and approach very close to one another anteriorly. Inferiorly they actually meet in the middle line. In the space between the eyes are the large basal joints of the antennæ. Beneath the origin of the antennæ are the combined clypeus and labrum with the proboscis.

The head is connected with the thorax by a narrow membranous neck, in which are two lateral chitinous plates (cervical sclerites).

The Thorax.—This, as in other insects, consists of three segments, the pro-, meso-, and meta-thorax. Of these, as in other diptera, the mesothorax is the larger, and the prothorax is very small.

Each segment consists of a dorsal piece or notum, a ventral piece or sternum, and a lateral portion or pleuron. In the well-developed meso-thorax the notum consists of several portions, of which the large scutum and the smaller scutellum and post-scutellum are readily seen. In the other segments these divisions are not readily made out. Both in the meso- and meta-thorax the pleuron consists of two large plates, the epi-merum and epi-sternum of each segment respectively.

The prothorax is collar-like in shape. The pronotum is undeveloped, but on either side of the base of the neck are two conspicuous processes, which consist of two freely movable plates (patagia).

From these, on either side, pass downwards the two rod-shaped pleural bodies connected below with the prosternum.

The mesothorax forms the greater part of the thorax. There is a large ovoid scutum. Posterior to the scutum there is a thick transverse ridge, the scutellum, which shows very prominently in longitudinal sections. Posterior to this, and forming the roof of the thorax behind the wings, is a large plate, which sends inwards a process, and to which the posterior portion of the great antero-posterior wing-muscle group is attached. The mesosternum forms two large surfaces behind the first pair of legs, and projects laterally above the middle coxa. The episternum and epimerum are two large plates placed laterally. In the pleuron of the mesothorax is the largest spiracle of the body, the first thoracic stigma. Several small detached plates are present in its neighbourhood.

The metathorax is narrow and ring-like. It bears the halteres or homologues of the second pair of wings in neuroptera, &c., and also a large spiracle, the second thoracic stigma. From the notum and sternum large chitinous processes project inwards (apodemes). These give attachment to both thoracic and abdominal muscles.

The Abdomen.—The abdomen consists of eight segments. Each consists of a tergum and sternum connected laterally by the pleural membrane. The pleural membrane continues unbroken throughout the length of the abdomen, and carries the abdominal spiracles, one opposite each segment. From the last segment project two flap-like processes, which are used in the deposition of ova.

The Wings.—The wings arise from the mesothorax. They are not directly associated with the main masses of wing muscles which are inserted into the walls of the thorax. The variation in the shape of the thorax caused by the contractions of the muscles causes the up and down movement of the wings.

The Legs.—The legs arise from each segment of the thorax. The proximal joint is the large coxa. Between this and the femur is the small trochanter. The other joints are the tibiæ and tarsi.

The Alimentary Canal.

The alimentary canal is specialised on account of the blood-sucking habits of the mosquito. It differs from many insects in not possessing any cæcal diverticula of the mid-gut. It also differs in the possession of five Malpighian tubules, these being in insects usually even in number. (Plate 1, fig. 2.)

The parts of the alimentary canal are as follows :—

The mouth The pharynx with pumping organ The œsophagus The œsophageal diverticula	The fore-gut.
The homologue of the proventriculus The stomach (so-called) The pylorus	The mid-gut.
The pyloric dilatation The small intestine The colon The rectum with rectal papillæ	The hind-gut.

The mouth, pharynx, and œsophagus are ectodermal in origin, and both the mouth and pharynx are lined with chitin. The hind-gut is also ectodermal in origin; it does not possess, however, any portion lined with chitin. The mid-gut is the true digestive portion of the tract.

The Pharynx.—The pharynx, which is lined throughout its extent with chitin, passes upwards and backwards through the ganglionic ring formed by the supra- and infra-œsophageal ganglia and their commissures. At first it is narrow, but posteriorly becomes a large chamber (the pumping organ).

The pumping organ occupies with its muscles a large portion of the head behind the level of the cerebral ganglia. In the state of rest its lumen is triradiate in transverse section. The walls are formed of three large and thick chitinous plates, one placed on either side and one superiorly. Into each of these plates powerful muscles are inserted. Those of the superior plate consist of two muscular masses, taking their origin from the occiput. Those of the lateral plates consist on each side of a single large muscular mass arising from the lateral portions of the head. The plates are connected by thin non-chitinous membrane, and their edges are rolled so that they form a

spring capable of returning to their original position so soon as the separating force of the muscles ceases. (Plate 1, figs. 3 and 4.)

Posteriorly, where the pharynx becomes very narrow, a sharp bend occurs and a valvular action is produced. The whole forms a very powerful suctorial apparatus.

The Œsophagus.—Immediately beyond the pumping organ the chitinous layer ceases, and the rest of the fore-gut is formed of excessively thin membrane. At the junction of the two portions a sharp bend occurs, and the floor projects so as to form a valvular flap.

The thin-walled œsophagus is a large dilated sac, whose walls are supported by surrounding structures. Into the posterior wall of the dilated and thin-walled œsophagus projects the papilla-like anterior portion of the mid-gut.

The Diverticula of the Œsophagus.—From the œsophagus two or three diverticula, similar in nature to the œsophagus, extend backwards. Of these one is of great size, and usually contains air. This most usually extends into the abdomen, and is a prominent object in dissections and sections. In the newly-hatched mosquito it is small, but rapidly becomes large enough to extend into the abdomen. (Plate 1, fig. 3.)

The Homologue of the Proventriculus.—There is no true proventriculus as in many insects. There is, however, an interesting fold of the fore-gut into the mid-gut which represents this organ. The anterior portion of the mid-gut has been noted as projecting into the dilated œsophageal pouch. This portion consists of both ectodermal and endodermal portions, and represents the proventriculus in other insects (see "Histology," Part II). The muscular bundles are here increased, and the whole forms a valvular muscular organ. (Plate 1, fig. 3.)

The Mechanism of Feeding.—The powerful pumping action which must result from a drawing asunder of the three large chitinous plates of the pumping organ is very evident. These plates, also, when drawn apart must, by reason of their spring-like shape, revert to their original positions close together, without any muscular aid. Posteriorly the valve-like arrangement mentioned before prevents regurgitation.

In mosquitoes as usually killed, the proventriculus and anterior portion of the mid-gut are considerably distant from the posterior end of the pumping organ, so that the large delicate walled œsophageal chamber with its extensive diverticula intervene. Immediately after feeding, however, though blood is very evident in the mid-gut, and even in the calyx-like proventriculus, yet in the œsophagus there is no trace. As this latter is so large and has such delicate walls, it is evident that, in the act of feeding, the calyx-like proventriculus must be applied directly to the posterior opening of the pharynx, thus shutting off the capacious œsophageal pouch. The large œsophageal

diverticulum probably acts, not only as an air chamber to specifically lighten the body of the mosquito, but also as an air pad to distribute the pressure of the large coagulum formed in the mid-gut after feeding. In a fed mosquito a transparent area is generally to be seen in front of the opaque mass of blood in the abdomen. This transparent area is the abdominal portion of the air-containing œsophageal diverticulum. (Plate 1, fig. 3.)

The Mid-gut.—The mid-gut extends from the proventriculus to the origin of the Malpighian tubes. It consists of two portions which merge into one another—an anterior narrow portion, and a large dilated posterior portion, which becomes greatly distended after feeding. Unlike most insects there are no cæcal appendages in the mosquito. Posteriorly there is a marked constriction, with strong muscular bundles, which forms a very marked pylorus. (Plate 1, fig. 2.)

The anterior narrow portion of the mid-gut lies in the thorax, and does not become distended with blood. The posterior portion when fully dilated fills the greater portion of the abdomen, the viscera being pushed into the last few segments. (Plate 3, fig. 2.)

The Hind-gut.—The hind-gut is short and passes in one or two bends from the pylorus to the anus. Immediately beyond the pylorus there is a considerable dilatation which is poorly supplied with muscular fibres: into this open the five Malpighian tubules. For a short distance beyond this the lumen is narrow (small intestine), but becomes gradually larger (colon). At the termination of the colon there is a slight constriction, after which the canal dilates again to form the rectum. (Plate 1, fig. 2; also Plate 3, fig. 1.)

Into the rectum project six solid growths, the so-called rectal glands, which are, however, papillæ. Posteriorly the rectum ends in the anus close above the gynæphoric canal.

The appendages of the alimentary canal are:—

The Salivary Glands.—The salivary glands consist of six tubular acini lying three upon either side. Those of one side lie generally one above the other in the long axis of the body, their anterior ends lying close against the prosternum, where the ducts coming from each acinus unite to form a single duct. The upper and middle acini generally lie with their distal ends close to the proventriculus. The lower acinus passes towards the thoracic ganglion. Occasionally an acinus becomes bifid at a short distance from its termination. A common abnormality also is a small accessory acinus near the proximal end of an acinus. A duct can be seen traversing almost the entire length of each acinus. Shortly after leaving the acinus the three unite to form a single duct. The duct of each side passes up into the neck, and lies close to the nerve cords passing between the thoracic and the cerebral ganglia. Beneath, and in contact with the lower surface of the sub-œsophageal ganglion, the ducts of each side unite to form a common

salivary duct which passes forwards and enters the chitinous first portion of the alimentary canal close to the base of the proboscis.

The Malpighian Tubules.—These are five in number and open into the first portion of the hind-gut immediately beyond the pylorus. Their blind ends are held in position in the neighbourhood of the rectum by tracheal branches. They pass forwards in loops above their origin, so that, in transverse section, as many as ten may be seen cut across.

The Muscular System.

The chief muscular masses in the mosquito are contained in the thorax. They are chiefly muscles moving the wings and legs.

Wing Muscles.—There are two large muscular masses on either side of the thorax, passing from the dorsal to the ventral body wall. Between these bundles there is a space, in the lower portion of which lies the alimentary canal, main air tubes, and other structures. The upper portion of the space is occupied by a second series of large muscular bundles, passing from the front to the back of the thorax. Neither of these large masses of muscle are inserted directly into the wings, the up and down movement of the wings being caused by alterations in the shape of the thorax, consequent on the contractions of the vertical and horizontal fibres respectively. (Plate 2, figs. 4 and 5.)

There are, however, a few fibres arising from the lateral portions of the thorax, and inserted about the base of the wings.

Leg Muscles.—These occupy but little space in the thorax. They rise to a large extent from the internal processes of the exoskeleton (apodemes), and are inserted into neighbouring portions of the limbs. They arise also from one segment of a limb and are inserted into another.

The Muscles of the Body Segments.—These arise from one segment and are inserted into the next. They are arranged dorsally and ventrally in lateral groups throughout the abdomen.

A small muscle is also situated on each side, passing vertically from the tergum to the sternum. These on contracting flatten the abdomen.

Muscles in association with the Alimentary Canal.—Several important muscular masses are connected with the large chitinous pumping organ. A pair of muscles arises from the occipital region of the exoskeleton, and is inserted into the upper plate of the organ. A large muscle arises on each side, and is inserted into each of the lateral plates.

In the thorax a small muscular band rises from the neighbourhood of the first pair of legs, and passes upwards close to and outside the salivary glands of each side. The contraction of this band must exert pressure upon the salivary glands. (Plate 2, figs. 1 and 2.)

Anteriorly and posteriorly small muscular bundles pass from the dilated portion of the mid-gut to the abdominal wall.

The Tracheal System.

Respiration is entirely carried on by tracheæ. These take their origin from external openings—the spiracles, and eventually terminate in minute capillaries in the actual tissues of the insect. In culex and anopheles there is no development of large or multiple air sacs in connection with the tracheal system, as in many insects. In their case probably the large œsophageal diverticulum plays the same part.

The spiracles are placed both in the thorax and in the abdomen. The thoracic spiracles are two in number, situated in the meso-thoracic and meta-thoracic segment respectively. Of these the anterior one is the largest in the body. The second thoracic spiracle is also much larger than the abdominal spiracles. The abdominal spiracles are situated in the pleural membrane, one in each segment. (Plate 1, fig. 1.)

The Tracheæ.—Very large tracheæ pass inwards from the anterior thoracic spiracles. (Plate 2, fig. 3.)

1. A large branch passes forwards towards the neck and gives off a branch which passes down on either side of the middle line to the two anterior coxæ and the salivary glands. The main branch continues on through the neck, and supplies the head with numerous large branches.

2. A large branch passes upwards and backwards along the edge of the meso-scutum, and gives off branches which supply the wing muscles. A smaller branch also passes forwards and supplies the muscles of the thorax.

3. The largest trachea in the body (main trachea) passes downwards, backwards, and inwards, so as to lie on either side of the anterior portion of the alimentary canal. Numerous branches are given off from this trunk to the thoracic muscles, the alimentary canal, and legs. Posteriorly the trunk is continuous with a trachea passing forwards from the second thoracic spiracle, thus forming on either side a large tracheal loop.

Large tracheæ also pass inwards from the posterior thoracic spiracles.

1. Branches pass forwards and join in a loop with the main trachea, also backwards to join the abdominal system.

2. Branches pass downwards to the meta-thorax and posterior pair of legs.

3. Branches pass inwards to the muscles and mid-gut.

From each abdominal spiracle a short thick trunk passes inwards which gives rise to the following branches:—

A dorsal branch ramifying beneath the tergum and joining the branch of the opposite side.

A sternal branch supplying the sternal plate and muscles, also joining the branch of the other side.

Loop branches passing to the trunks anterior and posterior.

Branches passing inwards and supplying viscera. Branches from the first, second, third, and fourth abdominal tracheæ supply mainly the mid-gut, those from the fourth and fifth the ovaries, those from the sixth and seventh the genital organs.

The Vascular System.—As in most insects where the respiratory system ramifies throughout the whole body, the vascular system is not well developed. A dorsal vessel or heart and an anterior prolongation of this (aorta) are the only closed blood vessels. Apart from the dorsal vessel the blood circulates in large blood spaces, which lie between the lobes of the fat-body and among the muscles and viscera.

The dorsal vessel passes close beneath the tergal plates throughout the abdomen. It is very thin walled, and is not provided with valves. The upper portion is attached to the dorsum at intervals by suspensory fibres (muscular), so that a festooned appearance is given in longitudinal section. There is, however, no true division into compartments. Laterally large cells (pericardial cells) are arranged throughout its entire extent, and fibres of a muscular nature (alary muscle) pass from the body wall and end in branches in close connection with the dorsal vessel (see "Histology," Part II). (Plate 4, fig. 1.)

At the first abdominal segment the dorsal vessel dips down beneath the mesophragma, lying as it does so, in direct contact with the cuticle. In the thorax it again arches upwards, and lies between the lower portions of the antero-posterior wing muscles close above the anterior portion of the mid-gut.

In the anterior third of the thorax it divides into two smaller portions which pass outwards, and coming in contact with the salivary ducts enter the neck.

Blood spaces without definite walls occur throughout the body. The thorax especially contains large spaces among the muscles, and the complex fat-body which lies between and supports the organ is everywhere bathed with blood fluid. (Plate 1, fig. 3.)

The Nervous System.

The ganglionic system in the Culicidæ is considerably developed. The head ganglia are large and complex. The thoracic ganglia are large and compressed so as to form a large ganglionic mass. The ganglia of this system are as follows:—

a. Lying around the pharynx is a ganglionic ring composed of large supra- and infra-œsophageal ganglia with their commissures. From these, large nerves go to the eyes, antennæ, and mouth parts.

b. In the thorax lying below the œsophageal diverticulum and close to the sterna is a large compound ganglion showing evidence of its

origin from the conjoined ganglia. Between this and the head ganglia are two long slender nerve cords, which pass in the neck in close relation with the salivary ducts. From the thoracic ganglion large nerves pass to the limbs, and posteriorly nerve cords connect it with the first abdominal ganglion.

c. The abdominal ganglia lie with their connecting commissures close upon the abdominal sterna. The last ganglion lies just below the junction of the oviducts to form the common oviduct. A large nerve passes from it among the viscera of the last few segments.

The Visceral System.—Small ganglia connected with the main ganglionic system occur in connection with the viscera. The most important of these are two small groups of large nerve cells lying in front of and above the thoracic ganglion, with the middle portion of which they are connected by nerves. They lie laterally beneath the œsophageal diverticulum and anterior portion of the mid-gut, and are not far removed from the salivary glands. Another small ganglion occurs above and in front of the proventriculus. (Plate 4, fig. 5.)

The Reproductive System.

The organs of the reproductive system are—

1. Ovaries.
2. Oviducts and common oviduct.
3. Mucus gland and duct.
4. Spermathecæ and ducts.

The ovaries occupy a variable position dependent upon the state of their development. In the newly-hatched mosquito they are small bodies lying in the fourth and fifth abdominal segments close by the posterior portion of the mid-gut, and attached to the body wall by numerous tracheæ. As they enlarge they push the mid-gut, hind-gut, and Malpighian tubes towards the ventrum, so that eventually the ovaries occupy nearly the whole of the posterior portion of the abdomen. Each ovary consists of very many follicular tubes, each containing egg follicles in different stages of development (see "Histology"). In the mature ovary the lower follicles have in every tube become the large completely-formed egg. (Plate 6, fig. 5.)

The oviducts are muscular tubes passing from the ovaries. They join beneath the rectum to form the common oviduct, which is still more abundantly supplied with muscle fibres, and which eventually opens beneath the anus.

The spermatheca is a chitinous sac, which in the impregnated female is filled with a mass of spermatozoa. Its duct is long and twisted and opens into the common oviduct near its termination.

The mucus gland, globular or ovoid in shape, opens by a short duct into the same region.

The Fat-body.—The adipose tissue is disposed in two ways.

1. As a general lining to the body wall, being nearly everywhere present directly beneath the cuticle (Plate 3, fig. 1), and

2. As lobular masses lying in among the organs and muscles. Thus a large pad lies over the compound thoracic ganglion, and sends processes which lie in among the salivary glands and other viscera. Other smaller masses lie in the head and abdomen. (Plate 1, fig. 3.)

Part II.—Histology.

Methods.—The examination of the fresh tissues frequently reveal structures not easily seen in fixed preparations. The tissues are best dissected out in normal saline of low tonicity, 0·3 or 0·4 per cent., as insect juices have a lower isotonic point than those of mammals. Better preparations of both tissues and included parasites are usually to be obtained by the use of fixed tissues. Several tissues (including the salivary glands and mid-gut) may, when dissected out, be spread by means of the edge of a slide or cover-glass, and rapidly dried. These, fixed and stained, give beautiful preparations of sporozoites, as well as certain parasites in the mid-gut, hind-gut, &c.

For fixing mosquitoes as a whole, watery solutions are not generally so good as alcohol, on account of the difficulty of penetration from the nature of the exoskeleton and the large amount of air contained in insect tissues: very good results are obtained by fixing and hardening in absolute alcohol, and proceeding at once to embed in paraffin. It is best, so soon as considerable hardening has taken place, to make a minute incision into both the thorax and abdomen. For fixing portions of or isolated organs of mosquitoes saturated solution of perchloride has advantages over alcohol and fixes the cells of the mid-gut extremely well. It does not penetrate, however, well into undissected mosquitoes. Picric acid gives good results with isolated organs. The changes in the mid-gut cells during digestion are well shown.

Both Culex and Anopheles, but especially the latter, cut readily in paraffin or celloidin. For staining smear preparations and sections hæmatein gives very good results: sporocysts and sporozoites, as well as the normal tissues, are well stained.

The stellate cells in connection with the tracheal endings upon the mid-gut, &c., are frequently well shown by gold chloride. Heidenhein's hæmatoxylin gives good results with the salivary glands, and also the muscle fibres in connection with the alimentary canal.

The Histology of the Alimentary Canal and Appendages.

The epithelial lining differs considerably in the mid-gut from either the fore-gut or hind-gut. In the mid-gut the possession of a marked

striated border by the epithelial cells is characteristic. The muscular fibres of the alimentary canal are striated throughout.

The Fore-gut.—The anterior portion of the fore-gut is lined by chitin and does not differ from the cuticle in structure. It consists of a single layer of cubical cells of small size. The œsophageal dilatation and its diverticula resemble one another in structure. In the adult mosquito they consist of an extremely delicate membrane formed of a single layer of flattened cells, with externally some scattered muscular fibres. In fresh preparations peculiar wrinklings of this membrane are seen which may appear like bundles of sporozoites. A similar appearance is seen in the dilated portion of the hind-gut just beyond the pylorus.

In the pupa the œsophageal diverticulum is seen passing backwards as a narrow tubular organ lying beneath the mid-gut. It is in this stage lined with well-marked cubical epithelium. In a freshly-hatched mosquito this organ is frequently undistended, and shows a narrow lumen surrounded by a single layer of large cells. These cells retain very little trace of protoplasm, which, however, may still be present in fine strands, and around the nucleus, which is pushed to the outer portion of the cell. (Plate 4, fig. 5.)

In the majority of mosquitoes the walls of the œsophageal diverticulum are crowded with micro-organisms and bodies which appear to be protozoal in nature.

The Mid-gut.—There is but little structural difference between the narrow anterior portion of the mid-gut which lies in the thorax and the posterior dilated portion which lies in the abdomen. In many insects there are cæcal tubes or pouches opening into the anterior portion of the mid-gut. These are, however, quite absent in the adult mosquito. The main thickness of the wall consists of epithelium; external to this is a thin coat of muscle fibres. (Plate 4, fig. 2.)

The epithelium consists of a single layer of large cells which are columnar in the undistended organ, but become flat and pavement-like when the organ is full of blood. They have a finely-reticulated protoplasm, which stains more deeply towards the free border. Stained with Heidenhein's hæmatoxylin, alcohol-hardened specimens are seen to contain numerous stained granules collected especially in the outer portion of the cell. These are especially abundant in the anterior portion of the mid-gut. They have also very frequently a number of small clear vacuoles (droplets) which become more frequent and of larger size towards the free border of the cell. The most marked feature of the cell is the clear striated border which is present in all the cells of the mid-gut, but absent in all other portions of the alimentary canal. The striated border is best marked in the undistended organ and becomes almost invisible in the fully distended state when the cells are much flattened. (Plate 5, fig. 1.)

The nucleus of these cells is large and centrally situated. The chro-

matin is arranged in small stellate masses arranged circumferentially and centrally and connected with one another by fine threads of chromatin. There is a body which stains less deeply generally to be made out (karyosome) in the centre of the nucleus.

Occasionally young cells are to be seen near the basement membrane.

The muscular coat is very thin. It consists of an open mesh-work of long muscle fibres running longitudinally and circularly. In the large posterior portion of the mid-gut these fibres form a very regular series of large square or rhomboidal meshes. In the narrow anterior portion they are more closely approximated so that the muscular layer here is more evident in sections.

The individual muscle fibres are very long, fusiform, striated fibres. On the outer surface of the mid-gut lie numerous large branched cells in which the small traçheæ end, and from which bundles of minute structureless air tubes pass into the wall of the mid-gut. These cells are frequently well shown in gold chloride specimens. Similar cells occur throughout the viscera in connection with the tracheal endings. (See "Tracheal Endings.")

The Homologue of the Proventriculus.—Mention has been made in Part I of a fold occurring at the anterior extremity of the mid-gut. This consists of an invagination of a portion of the fore-gut into the mid-gut. The mid-gut is also folded in with the portion of fore-gut, so that in this region there is a double thickness of mid-gut wall as well as the fore-gut. There is an increase in the muscular fibres of the mid-gut at this point, especially the circular fibres, so that a very distinct mass is formed homologous to the proventriculus of many insects. There is no chitinous development, however, and the structure would appear to act only as a muscular sphincter. (Plate 1, fig. 3.)

The Hind-gut.—The nature of the epithelium and arrangement of the muscle fibres differs somewhat in different portions of the hind-gut. Structurally the small and large intestine are similar, whilst the dilatation beyond the pylorus, and especially the rectum, differ from these.

The dilatation which occurs at the origin of the Malpighian tubules is thin-walled and poorly supplied with muscle fibres. The cells lining it are small and flattened. (Plate 3, fig. 1.)

The intestine is lined with a single layer of large cubical cells: external to these is a muscular coat. The cells of the intestine have large nuclei which have a similar, though more open, arrangement of the chromatin than the nuclei of the mid-gut. The protoplasm is finely reticular, and stains less deeply than the cells of the mid-gut. Stained with Heidenhein's hæmatoxylin, no granules are present as in the cells of the mid-gut. They have no striated border. (Plate 4, fig. 3.)

In the rectum the cells become small and flattened. There are, however, here bodies usually termed rectal glands. These are papillæ

covered with a single layer of much hypertrophied cells resembling those lining the small intestine and colon. (Plate 4, fig. 4.)

The muscular system of the hind-gut is very similar to that of the mid-gut, consisting of very large fusiform, striated cells arranged circularly and longitudinally. The circular fibres in the small intestine lie outside the longitudinal, and pass spirally around the mid-gut. Towards the termination of the intestine longitudinal fibres also lie outside the circular. In the rectum and extending throughout the hind-gut and mid-gut, in both Anopheles and Culex, there are, in a large proportion of specimens, swarms of a flagellate organism. (Plate 5, fig. 3.)

The Salivary Glands.—The salivary acini lie in a cleft in the fat-body, which latter comes in close contact with the glands. Each gland acinus consists of a single layer of large cells limited externally by a delicate sheath (basement membrane) and internally by the intra-glandular duct wall. (Plate 5, figs. 6 and 7.)

In Anopheles the intra-glandular duct becomes larger as it approaches the termination of the acinus, and forms a large cavity.

In Culex the duct remains of the same diameter throughout the acinus, and terminates abruptly near the end of the acinus without any dilatation.

In both Culex and Anopheles there are two types of gland acinus. These are recognisable both in the fresh gland and in fixed specimens. From their appearance in the latter they may be termed

(1) The granular type.
(2) The clear or colloid-like type.

The Granular Type.—The greater portion of the acinus consists of cells whose nucleus and protoplasm has been pushed to the outer portion of the cell by a large mass of secretion which occupies almost the whole of the cell. In the fresh gland this secretion appears as a clear refractile substance, and can by pressure be made to exude from the cell in refractile globules. In specimens hardened in alcohol, this clear secretion appears as a granular mass occupying the greater portion of the cell. It stains faintly with hæmatein, and shows under high powers ($\frac{1}{16}$ oil immersion) a coarse reticulum and isolated globules, an appearance probably due to the precipitation or coagulation of the secretion by the alcohol. Considerable variations exist, however, in the appearance of this granular secretion both in the different mosquitoes and in different parts of the same gland. In anopheles the greater portion of the gland contains cells densely crowded with granular material. Very frequently, however, the terminal portion contains cells in which only a few large globular masses exist. (Plate 5, fig. 9.)

The protoplasm of the cell occupies in the fully-matured gland only

the extreme periphery, and the nucleus, which is much degenerated, is pushed to the outer portion of the cell, and usually lies in the angular interval left at the base of two or more contiguous cells. In the granular type of gland this disappearance of the protoplasm and nucleus from view is more pronounced than in the clear type of gland.

The Clear or Colloid-like Type.—Of the last-mentioned type there are two acini upon either side; of the present type there is but a single acinus upon either side, which usually lies between the two acini of granular type. (Plate 5, fig. 7.)

In the fresh gland the cell outlines are not so distinct as in the granular type, and the secretion when extended by pressure is much less refractive. In alcohol-hardened specimens, the acinar cells contain a large mass of clear homogeneous secretion which, as in the last-mentioned type, fills almost the entire cell, and pushes the protoplasm and nucleus to the periphery.

In the clear type, however, the protoplasm is always in greater amount than is the case with the granular type, and the nucleus never becomes so greatly degenerated. The clear homogeneous secretion stains readily with hæmatein, and may even stain quite deeply. With Heidenhein's hæmatoxylin it frequently becomes almost black. It resembles very much in appearance colloid substance as it is seen in the mammalian thyroid.

In Anopheles this substance also distends the central duct space within the acinus. In this situation an appearance is sometimes produced which resembles faintly-stained sporozoites, but which is a normal condition.

The Maturation of the Glands.—In freshly-hatched mosquitoes both types of acinus consist of large glandular cells arranged round the lumen. These contain a large centrally situated nucleus, and have protoplasm containing a large number of coarse granules staining with hæmatein. In the portion of the cell nearest the lumen a vacuole of varying size is situated. This is the commencement of the large mass of secretion which, in the mature gland, occupies the entire cell. In the granular type of acinus the vacuole contains granules; in the clear type it resembles the colloid-like secretion. (Plate 5, fig. 8.)

Further Variations in the Cells of the Salivary Acini.—In the granular type of gland the greater portion of the acinus is composed of cells of the character described above. A portion, however, usually exists which differs considerably in structure. This portion adjoins the duct, and may in Anopheles reach as much as one-quarter of the entire gland in length. In this portion of the gland the cells are much smaller than those containing the granular secretion, so that the diameter of the acinus is much less here, and a sudden increase takes place when the portion containing the granular secretion is reached. The cells lying towards the duct differ from those lying towards the acinar end of this

portion. There is, however, no line of demarcation between them, the one gradually becoming changed into the other. In the centre of each cell is a clear body, pushing the nucleus and protoplasm to the outer portion of the cell. Towards the duct end in the centre of this clear substance is a darker portion continuous with the duct lumen. As the cells come to lie nearer the distal portion, this central dark lumen becomes obliterated. This structure, though present in Anopheles, may be absent in Culex. In certain Culex another variation in the gland cells frequently occurs. The portion of the gland lying close to the duct, instead of being less in diameter is greater. The cells composing this portion are columnar in shape, with centrally situated nuclei and no contained secretion.

In certain specimens it is not uncommon to find cells occupying a peripheral position, and not approaching the lumen, which contain a substance resembling the colloid-like secretion of the clear type of gland.

Changes after Feeding.—Very little change occurs in the glands after feeding. They are for the most part still quite full of secretion. Probably a very small amount only of secretion is used with each puncture.

The Ducts.—The intra-acinar ducts vary in Culex and Anopheles. In Culex they remain narrow and tubular throughout the entire length of the gland. In Anopheles they become large spaces in both types of acini, but especially in the clear type. The duct is lined throughout by a clear homogeneous skeletal material which is continuous with a similar substance dividing the cells of the gland from one another. Into the duct the secretion-filled cell opens by means of a small opening.

The duct after leaving the acinus, consists of a thick-walled tube, with a central spiral thread resembling the spirals in the trachea. The wall is homogeneous, but contains many nuclei.

The Malpighian Tubules.—The Malpighian tubules are tubular bodies with cæcal ends, which open into the hind-gut. The cells are extremely large, being, next to the pericardial cells, the largest in the body. Each cell contains a large nucleus, and contains numerous large granules, which stain feebly with hæmatein, but powerfully with Heidenhein's hæmatoxylin. Numerous fatty granules are also present. Each cell is wrapped round a central lumen, the cells being arranged alternately, so that a zig-zag appearance is given in section. The inner portion of each cell is markedly striated, the lumen being thus bounded by a striated area. In relation with these tubules, a large number of tracheæ and tracheal end-cells exist.

In certain conditions the Malpighian tubule cells may be found quite free from granules, though otherwise unchanged. This change occurs in mosquitoes with large numbers of a flagellate organism (previously noted) in the rectum and hind-gut.

The Muscular System.—The muscular fibres of the mosquito are with-

out exception striated. Those of the wings differ in structure very much from those of the limbs and body segments. The muscle fibres of the alimentary canal are large fusiform cells, with a single large nucleus with some surrounding protoplasm. The muscle fibres in connection with the heart are much branched. (Plate 4, fig. 2.)

Many of the fibres contain a very marked sarcolemma and space between this latter and the fibre. This space is usually seen occupied by extremely delicate branching threads, which stain feebly with hæmatein.

In the pupæ there exist some large cells of peculiar nature in association with the sheaths of the muscle fibres.

The structure of insect musele is described in many works on histology, and does not need repetition here.

The Tracheal System.—The larger tracheal vessels consist of a single layer of flattened cells with an inner chitinous layer. In smaller tubes the cells embrace the entire vessel, the nucleus frequently being bent around the lumen. The cells of the tracheal vessels contain numerous small clear vacuoles (chitin formation). The chitinous lining possesses a thickening in the form of a spiral thread, which may beeome unwound and lie stretched as a wavy thread in fresh preparations.

The smaller tubes contain the spiral thread until they become from 2 to 5 μ in diameter. They then divide to form bundles of excessively minute air eapillaries, which enter among the tissue cells. The division into capillaries takes place in the substance of large branehed cells situated at the termination of the tracheal vessels. The cells often appear cribriform in section from the number of air capillaries. These cribriform cells in connection with the tracheal endings are well seen in the mid-gut and Malpighian tubules. They are, however, seen best of all in the undeveloped ovary of the newly-hatched mosquito, which is extremely rich in bundles of capillary air tubes.

The Vascular System.—The dorsal vessel is a delieate walled tube composed of longitudinal and oblique fibres with a nucleated inner layer. The fibres may be traced directly from the terminations of the branched alary muscle fibres. The alary fibres break up into fibres which pass in close connection with the large pericardial eells, and eventually form (1) fibres passing into the dorsal vessel as longitudinal fibres, (2) fibres joining in an anastomosis in connection with the floor of the dorsal vessel. (Plate 4, fig. 1.)

The pericardial cells are extremely large cells lying on either side of the dorsal vessel throughout its whole extent. They are by far the largest cells in the mosquito, varying from 30 μ to 50 μ in long. diameter. They are elongate or pear shape in form and contain several nuclei. The nuclei usually show signs of degeneration. The peripheral portion of the cell stains more deeply than the central portion, which contains the nuclei and small stained granules. There are a eonsiderable

number of masses of a light yellowish pigment resembling that found in the large visceral ganglia cells. The fibres from the branches of the alary muscles pass over and around the pericardial cells to reach the dorsal vessel. From their structure and situation the pericardial cells appear to be of the nature of ganglion cells. (Plate 5, fig. 5.)

The Fat-body.—The fat-body, both where it occurs as a portion of the body wall and where it lies as free lobulated masses, consists of cells containing numerous oil globules. The cells are of considerable size, and their borders may be frequently traced as polygonal areas. The nuclei are oval in shape with a central mass of chromatin and chromatin threads. Besides oil globules the cells contain granules staining with hæmatein, and minute droplets of a highly refractile, dark substance, which gives the appearance of pigment. These droplets are larger in amount in old mosquitoes than in those freshly hatched.

The Nervous System.—The ganglia of the ganglionic system consist of an outer portion of nerve cells and an inner portion of non-medullated nerve fibres. Considerable complexity exists in the larger ganglia, especially the head ganglia. (Plate 5, fig. 4.)

The ganglia of the visceral system differ greatly from those of the ganglionic system. The ganglion cells are few in number and of large size. They possess clear reticular protoplasm, a little denser around the periphery than in the centre. Around the inner margin of the denser peripheral portion small stained points are arranged. In the centre a variable number of granules of yellowish pigment exist. (Plate 6, fig. 1.)

The Reproductive System.—Each ovary consists of a large number of follicular tubes whose lower ends open into the ovarian tube, and whose upper ends terminate in a delicate supporting filament (terminal filament). The apex of the ovary is formed of a single follicular tube whose filament is attached to the fat-body of the 4th segment.

Around the whole ovary there is a delicate nucleated sheath.

Each follicular tube contains one or more egg-follicles in different stages of development. In the freshly-hatched mosquito each follicular tube contains an undeveloped egg-follicle. As this develops, a second and a third undeveloped follicle appear above it, which again undergo development into mature eggs. The follicle at first consists of two to four large cells with large nuclei surrounded by a single layer of smaller epithelial cells. (Plate 6, figs. 2, 3, 4.)

The central cells then increase in size and number, so that many very large cells are contained in the now enlarged follicle. The surrounding epithelial cells also become larger, and rapidly increase in number so as to form a layer of regular cubical cells surrounding the follicle. The central cell nearest the ovarian tube is the ovum, the rest are nurse cells, and eventually disappear. Both the ovum and the nurse cells increase greatly in size. The nurse cells have clear

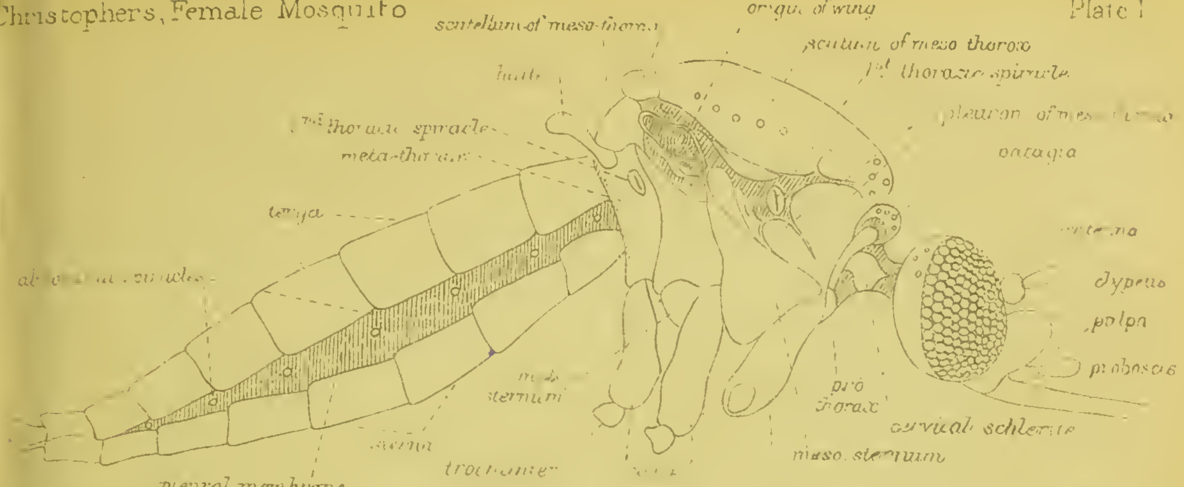
protoplasm and extremely large nuclei, which exhibit karyokinetic figures. The ovum contains very numerous yolk granules, which occupy the whole of its substance, except a thin coating of granular protoplasm. Still later this thin external layer can only with difficulty be made out. (Plate 6, fig. 4.)

The nucleus of the ovum undergoes very pronounced changes. It appears as an irregular mass, staining uniformly with nuclear stains. This mass becomes more and more distorted and broken up, and eventually disappears. It may frequently, however, be seen as irregular masses of staining material even in the mature egg. A portion of the nucleus is seen very early to be separated off from the rest, often surrounded by the latter. This portion (female pronucleus) is small and difficult to detect in sections in the more mature ovum. As the ovum increases still more rapidly in bulk, the nurse cells become crowded into the distal portion of the follicle and eventually disappear, so that, in the mature egg, no trace of them is to be seen. The epithelial layer surrounding the follicle becomes much flattened, and forms eventually a covering to the egg (chorion). The outer portion of this covering (exochorion) is transparent, and marked with oblique parallel markings. Over the proximal end, *i.e.*, the end lying towards the ovarian tube, the chorion forms a globular mass ornamented with rows of pits. This is the micropylar apparatus through which the spermatozoa penetrate the ovum.

Frequently in Anopheles a large portion or the whole of the adult ovum consists of a mass of sporozoa. These consist of numerous small cysts, each containing eight round or crescent-shaped bodies, each with a central chromatin spot. (Plate 6, figs. 6, 7.)

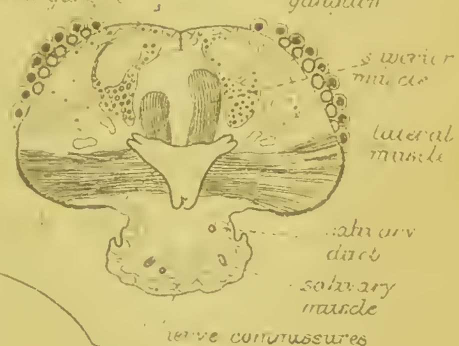
The ovarian tube arises in the centre of the ovary, and receives on all sides the follicular tubes. It is lined with a single layer of small cubical epithelium. After passing out of the ovary, a considerable number of striated muscular fibres are arranged in a loose network around it, and pass from it to surrounding structures. There are also muscular fibres in the ovary itself in connection with the ovarian tube and egg-follicles.

The spermatheca consists of a chitinous sac, with large cells lying externally. These resemble the cells of the cuticle, and contain droplets. They do not cover the whole of the surface of the spermatheca. The contents of the spermatheca in the fertilised insect consist of a mass of spermatozoa, which, in the fresh state, may be seen revolving with great rapidity within the sac. The spermatozoa have a narrow, slightly-curved head and a long tail. The duct of the spermatheca is narrow and thick-walled, and contains muscular fibres. Certain large cells lie in connection with the duct externally. The mucus gland contains cells filled with secretion. There are small nuclei in connection with the intra-acinar duct. (Plate 6, figs. 8, 9.)



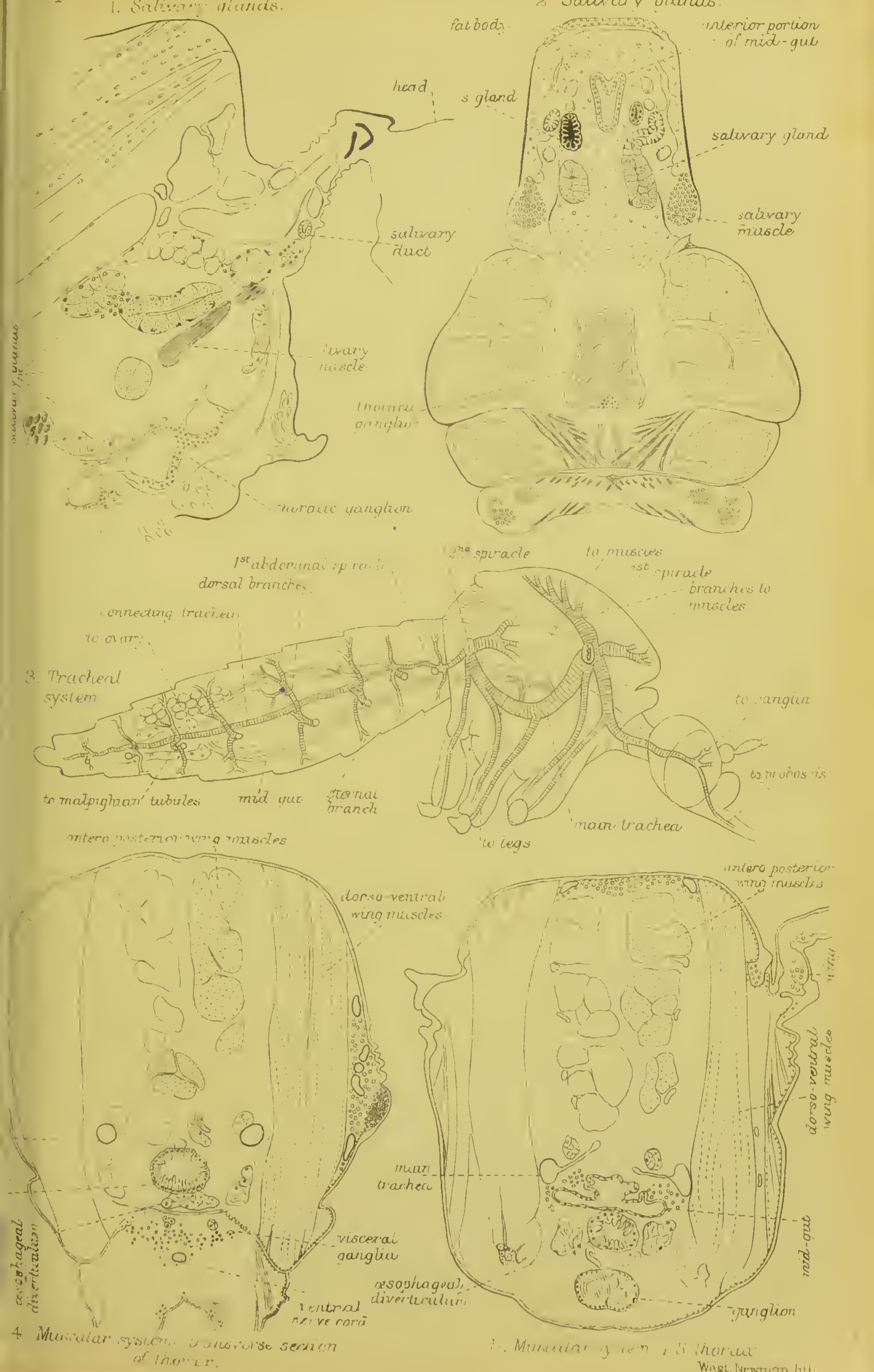
1. Exoskeleton

2. General view of organs.



3 Median longitudinal section through thorax.

West, Newman lith.



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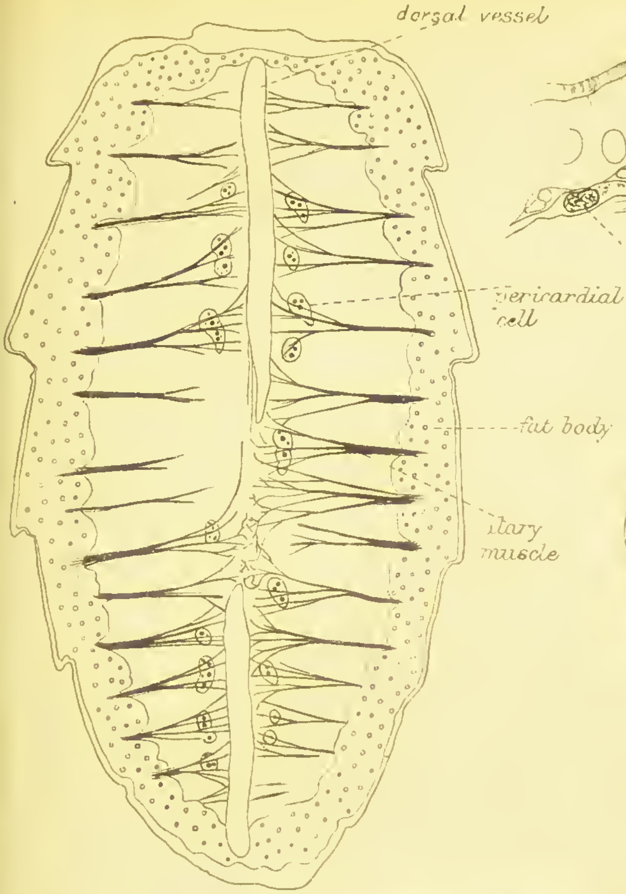
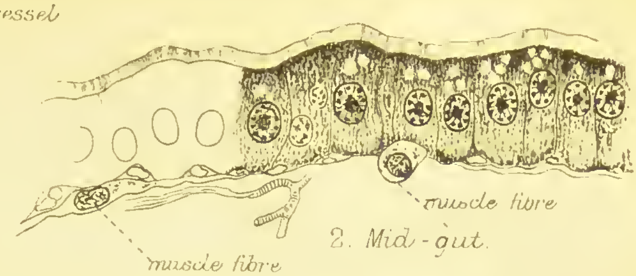
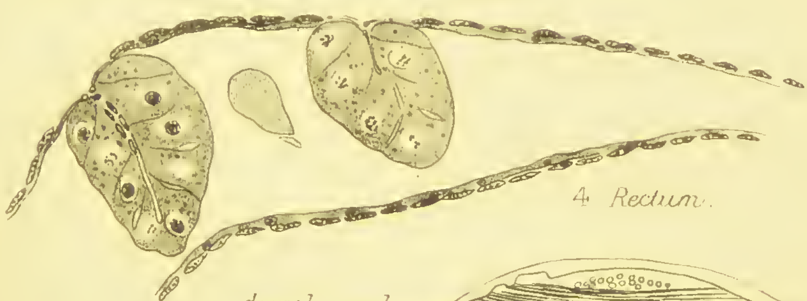


1. Dorsal vessel.

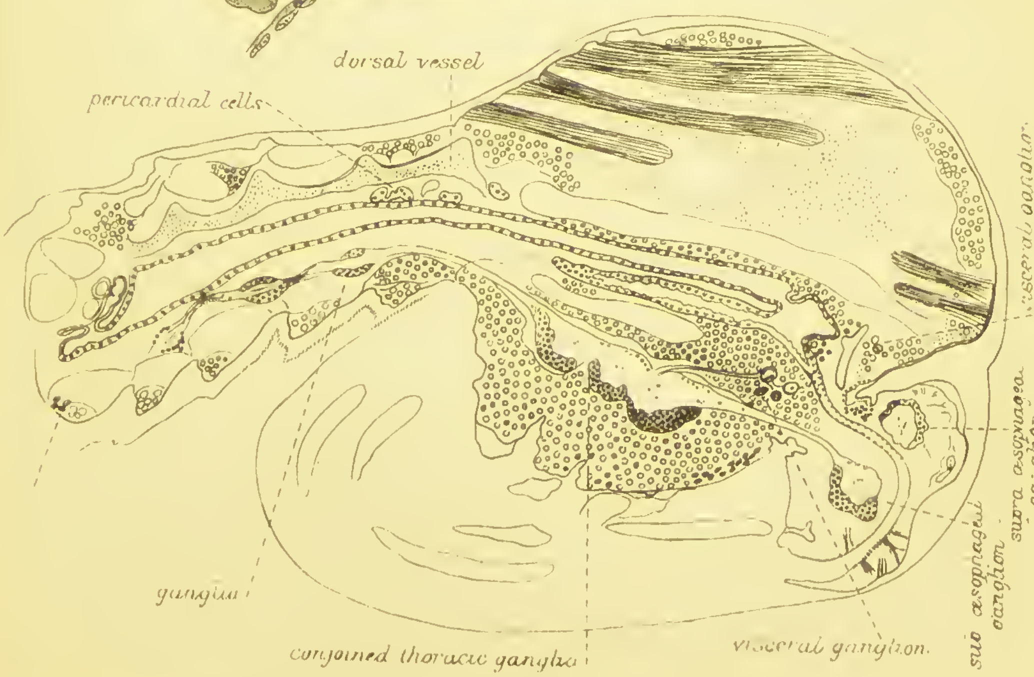


2. Mid-gut.

3. Hind gut.



4. Rectum.



5. Nervous system L. S. Section of nympha.

ROYAL SOCIETY.

REPORTS TO THE MALARIA COMMITTEE.

FIFTH SERIES.

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REPORTS, &c., FROM Messrs. STEPHENS AND CHRISTOPHERS, WEST COAST OF AFRICA.

"The Proposed Site for European Residences in the Freetown Hills." By J. W. W. Stephens, M.D. Cantab., and S. R. Christophers, M.B. Vict. Received November 26, 1900.

As a scheme for building European houses on the plateau above Freetown is under consideration, we, at the suggestion of Sir Frederick Cardew, K.C.M.G., investigated the neighbourhood of the proposed site. There are on these hills two straggling villages, Leicester and Gloucester, shown on the accompanying plan, but, apart from these, large areas are entirely free from habitations.

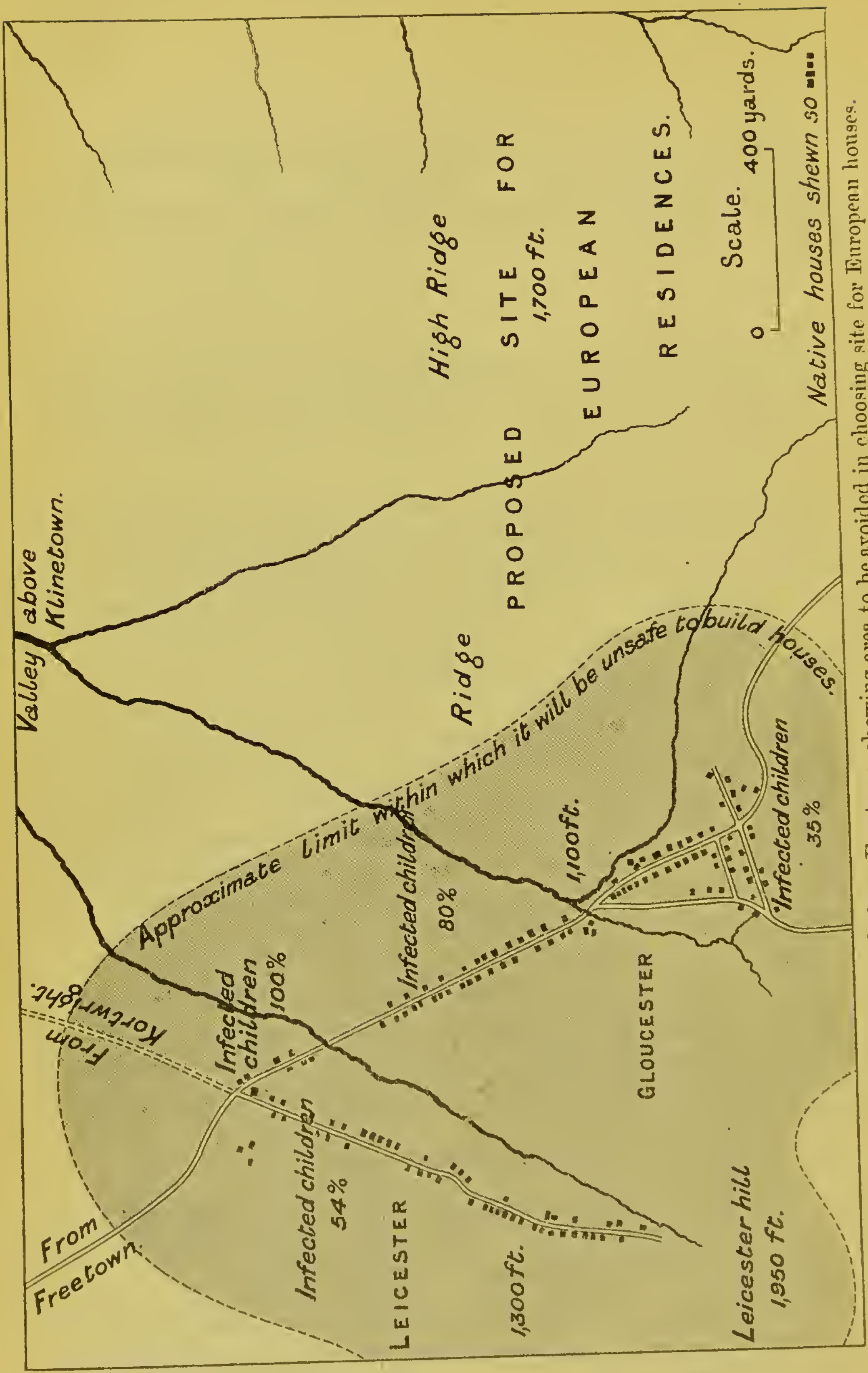
The children in Leicester and Gloucester show a considerable percentage of malarial infection, varying from 50 per cent. to 100 per cent. A portion of Gloucester, however, which is situated on a steep hillside, showed a diminished infection, namely, only 35 per cent. We believe the low figure observed in this part of Gloucester to be due to the extreme dryness of the hillside there, giving few opportunities for the existence of Anopheles, for elsewhere, as in Blantyre, at an elevation of 3000 feet, with numerous breeding grounds, malaria is rife.

There is, then, malaria on these highlands, and native quarters are here, as elsewhere, centres of malarial infection. Our surmise expressed in our first report on Freetown—that it would not be the elevation but the possibility of segregation which would make the scheme a success—was therefore correct.

We consider, then, that the proposed site—

(1) By reason of its remoteness from native dwellings;
(2) By reason of its dryness, if well chosen, giving few opportunities for Anopheles to breed;

will afford a complete freedom from malaria. It is essential, however, that native houses be rigidly excluded, and, as far as possible, native servants' quarters also. For we have seen elsewhere that even where breeding grounds are scarcely to be found, yet, under certain conditions, Anopheles, and these, moreover, infected, may occur.



Plan of portion of high ground above Freetown showing area to be avoided in choosing site for European houses.

It may be urged that we have overlooked the possibility of mosquitoes flying in from these villages, and as extraordinary statements

with regard to the flight of mosquitoes have lately appeared in print, it will not be out of place to record here our experience during nearly two years' residence in Africa in towns and in the bush under varying conditions:—

1. In Blantyre we occupied a house within 50 yards of Anopheles breeding grounds, and the house was naturally infested with Anopheles.

2. In a house 200 to 300 yards from the same breeding grounds we never observed any.

3. At Blantyre Hospital we never observed Anopheles, although breeding grounds were less than $\frac{1}{4}$ mile away.

4. In Freetown we have at different times occupied five houses, all less than $\frac{1}{4}$ mile, some much nearer, from innumerable breeding grounds, and in only one of these on one occasion did we observe Anopheles, and in that case the source was found in the neighbouring garden.

5. In Accra, in Bungalow 15, we never observed Anopheles, although plentiful less than $\frac{1}{2}$ mile away. Although in Accra it was stated that Anopheles flew in from a village 9 miles away, yet we found breeding grounds in profusion in Accra itself which completely explained their existence.

6. We have camped many nights a little distance ($\frac{1}{4}$ to $\frac{1}{2}$ mile) outside villages, and have not caught any Anopheles, though they were abundant in the villages.

These facts—and we could amplify them if necessary—must make it quite clear that Anopheles do not fly large distances, but remain in the neighbourhood of native huts, where they get a plentiful blood supply. From these they do often fly abroad, but it is at most a few hundred yards and not 15 miles.

Climatically, the change must be most beneficial. Even at an elevation of 700 feet (about half that of the proposed site) the atmosphere is fresh and even exhilarating, and one experiences the greatest relief after residence in Freetown with its most enervating foul atmosphere.

"The Increase in the Number of Large Mononuclear Leucocytes as a Diagnostic Sign of Malaria." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received November 26, 1900.

In our first report ("Malarial and Blackwater Fevers of British Central Africa," p. 20) we noted the occurrence of an increase in the

proportion of the large mononuclear cells—also described by other authors in malaria.

We further showed the relation of this change to the temperature curve. That usually this change is absent during the pyretic periods, but very pronounced in the apyretic periods, or immediately following the rise of temperature, if only one such occurs. We also noted that in certain cases this change was extraordinarily marked, the large mononuclears during the apyretic periods even outnumbering the polynuclear elements. Also that in certain cases the change was to be detected even during the pyretic periods, but that in these it was always still further evident in the apyretic. In others that during the course of the fever no such change occurred, but that it appeared immediately the temperature subsided, rapidly diminishing again during convalescence.

We also pointed out that this change was of the greatest diagnostic importance in cases of malaria which had been treated by quinine, and in which, therefore, parasites were extremely scanty or absent in the peripheral blood.

A discussion on cases of malaria in which parasites do not appear in the peripheral blood occupies an accompanying report. In these the use of two diagnostic points is usually sufficient to enable one to be certain of their nature, apart from the actual presence of parasites. These two diagnostic points are (1) pigmented leucocytes, and (2) the mononuclear increase.

(1.) Pigmented leucocytes, even in severe malaria, are often very few and often require for their discovery prolonged search in large films. In two cases, although very few pigmented leucocytes were found after long search during life, yet the examination of the spleen post mortem showed large numbers of pigmented mononuclear leucocytes. In other cases, however, they are abundant.

(2.) Often in a case where pigmented leucocytes are difficult to find, a glance is sufficient to show that there is an excess of the large mononuclear elements. In order to obtain accurate results, 1000 leucocytes should be counted, but a count of three or four hundred is generally sufficient for diagnostic purposes, and the numbers so obtained do not differ much from the value of more extensive counts.

In counting the leucocytes, a well-made film is requisite The film is spread on a carefully-cleaned *slide* by means of the shaft of a large needle. A drop of blood is taken up by touching it with the slide near one end. The drop is made to flow along the needle by a slight to-and-fro motion parallel to the surface of the slide, and the needle is then, with an even movement, carried along the slide. By this means a large and thin film is obtained. The leucocytes are gathered for the most part in the borders and terminal points of the film, and can now readily be counted.

The mononuclear increase :—

a. We have shown, then, in malaria this is an almost constant occurrence.

b. Further, in native children, for the same reason, the mononuclear value is rarely normal. The majority show a percentage of 20 to 30 per cent., or even much greater.

c. Finally, we believe from the results obtained (*vide* report on Summary and Conclusions on Blackwater) by leucocytic counts of a considerable number of Europeans living in the tropics, that an increase beyond 15 per cent. is proof of an actual or recent malarial infection, and indeed, with a value over 20 per cent., it is often possible by long search to find a pigmented leucocyte, and a value as high as this probably implies actual infection at the time.

The diagnostic value of this increase in cases where no parasites are present is, then, of great importance.

"Malarial Fever without Parasites in the Peripheral Blood." By J. W. W. Stephens, M.D. Cantab., and S. R. Christophers, M.B. Vict. Received November 26, 1900.

From time to time in the examination of Europeans suspected of having malarial attacks, and who presented a rise of temperature with more or less constant vomiting, headache, pains in the bones, &c., we have been forced to conclude against the diagnosis of malaria, as no parasites were found, even after repeated examinations, or the number of parasites was so scanty as to cause doubt if they could be causally connected with the attack. We refer to cases in which no quinine had up to the time of the blood examination been given, for in the presence of quinine no such conclusion from a negative examination would be justifiable. How frequent these cases may be we have no means of estimating, and further, as a rule, there is no means of proving conclusively that such cases are malarial.

We give the following instances of which we have notes :—

Case I.—J. Blantyre. Daily rises of temperature to about 100°. Then, after a few days, a tertian rise. Daily vomiting. It was only after prolonged examination for some days that a single ring-form parasite was found.

Case II.—S. Lagos. Well-marked subjective symptoms. Daily rises of temperature above 100°. Several blood examinations were made before any quinine had been taken. After prolonged search no

parasites were found. In a few days the temperature was normal. A leucocytic count now gave

Large mononuclears	24 per cent.
Small ,,	10 ,,
Polymorphonuclears	66 ,,

but no pigment was found. We felt certain that this was a case of malaria, and a re-examination of the blood taken, before quinine, now revealed, after again long search, one parasite, confirming thus the diagnosis based entirely on the leucocytic count.

Case III.—The following is a case where clinically there was not the slightest doubt as to the malarial nature of the attack, but there was absolutely no proof objectively.

C. Sierra Leone.

28.10.00. Evening temperature, 99·4°. Feeling unwell.

29.10.00. 5 P.M. Temp. 103°. Much vomiting. Blood examination negative. Quinine, 1·0 gramme. Mostly vomited.

30.10.00. 6 P.M. Temp. 100°. Vomiting continually. Blood examination negative. Quinine hypodermically.

		29th, 5 P.M.	30th, 8 A.M.	30th, 6 P.M.
Leucocytes :	Large mononuclears ...	16·4	15·2	15
	Small ,, ...	7	11·2	14
	Polymorphonuclears ...	76·6	73·6	71

The two cases of malaria produced experimentally in England by Anopheles brought from Italy, reported by Dr. Manson and Mr. Rees, also show this condition.

Case IV.*—P. M. Bitten by infected Anopheles. 29 and 31.8.00. Also on 2 and 4.9.00. Also 10 and 12.9.00.

13.9.00. 9 A.M. t. 99°. 4.30 P.M. t. 101·4°. Headache, lassitude, chilliness, pains in the back and loins. Repeated blood examinations negative.

14.9.00. t. ranged between 101° and 102°. Subjective symptoms exaggerated. No parasites.

15.9.00. 7 A.M. t. 100·4°. No parasites.
4 P.M. t. 103·6° Delirium. No parasites

16.9.00. 8 A.M. t. 98·4 One doubtful parasite.
7 P.M. t. 102·8°.

17.9.00. 10 A.M. t. 99°. Several parasites. Two pigmented leucocytes. Later many tertian parasites.

* "Experimental Proof of Mosquito Malaria Theory," Manson, 'Brit. Med. Journ.,' September 29, 1900, p. 950.

Had quinine been given on the 14th or 15th there can be no doubt that subsequent examinations would likewise have revealed no parasites.

Case V.—G. W.* Fed infected mosquitoes on his blood (? 14.8.00).

28.8.00.	Feeling ill. 5 P.M. t. 101·6°. No parasites.
29.8.00.	One pigmented leucocyte.
30.8.00.	Four pigmented leucocytes.
1.9.00.	8 P.M. t. 101°. No parasites.
2.9.00.	9 P.M. t. 102°. Midnight, 104·4° No parasites.
3.9.00.	Morning. Parasites.

The two cases illustrate the fact that a high temperature may occur for some days without the existence of parasites in the blood. For the purposes of the experiment quinine was not given until the diagnosis had been established. Had quinine been given early, as universally in practice is the case, there would have been no evidence of the existence of parasites in either of these cases. They are, then, of particular value as showing that *a high temperature persisting for some days is not necessarily accompanied by parasites*, so that the absence of parasites does not necessarily exclude a malarial infection.

We think that such cases as these are by no means isolated, and although, broadly speaking, it is true that there is no malaria without parasites in the peripheral blood, yet exceptional cases make it extremely important for diagnostic reasons that some other means (*e.g.*, a serum reaction) for the diagnosis of malaria be discovered.

Another class of cases in which the clinical symptoms of malaria are often pronounced, though no parasites occur in the peripheral blood, is seen after the taking of quinine in the course of an ordinary attack.

The following cases show how a high temperature may persist for some days, but, nevertheless, no parasites be found. In these cases parasites were detected before quinine had been taken, but more commonly the patient is not seen until after the administration of quinine, and then so far as parasites are concerned the examination is negative.

Case VI. C. 11.10.00. t. 102°. Numerous parasites.

Leucocytes	Large mononuclear ...	8·6 per cent.
	Small ,, ...	6·6 ,,
	Polynuclear	84·8 ,,

12.10.00. Thirty-six grains quinine since last examination. No parasites. No pigment.

* "Experimental Proof of Mosquito Malaria Theory," Rees, 'Brit. Med. Journ.,' October 6, 1900, p. 1055.

13–17.10.00. Thirty grains of quinine daily. High temp. No parasites.

18.10.00. First day of normal temperature.

No parasites. No pigment.

Leucocytes	Large mononuclear ...	30	per cent.
	Small " ...	15	"
	Polynuclear	55	"

Showing a well-marked mononuclear increase.

Case VII. M. 12.3.99. t. 104·8°. Parasites. Mononuclear increase.

13.3.99. t. 102·4°. Parasites. Mononuclear increase. Quinine.

14.3.99. t. 101°. Parasites scanty. Mononuclear increase. Quinine.

15.3.99. t. 101°. No parasites. Mononuclear increase. Quinine.

16.3.99. t. 101°. No parasites. Mononuclear increase. Quinine.

17.3.99. t. 100·4°. No parasites. Mononuclear increase. Quinine.

18.3.99. t. 99°. No parasites. Mononuclear increase. Quinine.

The bearing of the examples given above on the argument usually adduced to prove that blackwater is non-malarial, viz., that parasites are absent or in quite insufficient amount to account for the symptoms, is obvious. The argument fails; a complete absence of parasites in all cases of blackwater would not necessarily exclude malaria. Further, we believe that in a different class of cases, viz., those suffering from constant attacks of fever, who yet at the same time are more or less constantly taking quinine, parasites are frequently absent.

"The Tonicity of the Blood in Malaria and Blackwater Fever."

By J. W. W. Stephens, M.D. Cantab., and S. R. Christophers, M.B. Vict. Received November 26, 1900.

In our report on the "Distribution of Anopheles" in Sierra Leone, pp. 64 and 73, we appended some observations on the tonicity of the blood in malaria and blackwater fever. The method used was rough, and it was difficult to express accurately in words differences which, however, were quite well appreciated by the eye, and which could be best

expressed by some colorimetric method. Lesage,* using such a method, expresses his data in the form of a curve, and the results are more striking and easily followed. As we had no convenient means of estimating the hæmoglobin set free by the various solutions used, the following method was devised as being an improvement on that previously used, and capable of fairly accurate expression in numerical values, which could if necessary be represented in the form of a curve.

The stem of the ordinary Thoma-Zeiss pipette is divided into ten divisions. The drop of blood used for making the observation of tonicity was that contained in two of these divisions, so that five observations could be made simultaneously with the same specimen of blood taken from the patient's finger.

Four salt solutions were used, viz., 0·41, 0·39, 0·37, 0·35 per cent. In a control experiment, then, two divisions of the blood in the pipette were added to 1 c.c. of each solution in a small test tube. The last two divisions were added to 1 c.c. of water. Complete hæmolysis, of course, takes place in this solution. The colour given by this was for convenience' sake called 100 per cent. Solutions were also prepared in water, and this can be readily done, for purposes of comparison in which the amount of hæmoglobin was 90, 80, 70 per cent., etc., to 10 per cent. So that we had a series of standards with which the colour in the respective tubes containing salt could be compared.

These standards have the advantage of being solutions of Hgb., like that resulting from hæmolysis. They have the great disadvantage that they are not permanent.

In making an observation of tonicity, 1 c.c. of each of the four salt solutions was used, and the fifth tube contained water. The colour of this tube being now compared with that of the controls, the amount of Hgb. could be readily determined in terms of the standard control. A correction for differences in the amount of Hgb. in the tube containing water is necessary, otherwise a low reading may give a false view of the amount of hæmolysis, which may actually be greater than the control in a case where it is apparently less. On the other hand, the amount of hæmolysis in a malarial patient, is really less than it should be if no correction is made for anæmia.

Examples of the tonicities in malaria and blackwater fever are:

	0·41 per cent. salt.	0·39 per cent.	0·37 per cent.	0·35 per cent.	H_2O.
I. Malaria, 1...	25	40	60	—	—
II. " 2...	40	65	80	90	90
III. Control.....	0	20	65	90	100
IV. Blackwater..	0	0	0	20	—

* Lesage, 'Comptes Rendus Hebdomadaires de la Soc. de Biol.,' Juillet 28, 1900, p. 719.

The observations on the tonicity in malaria are quite in accord with those we have previously recorded.

In the blackwater case we did not at the time observe the value with water, but the anæmia was quite insufficient to account for the low tonicity which we have observed also in three other cases; in the remaining cases it was the same as the control or slightly raised.

We may summarise here these and our previous observations.

1. In malaria we have constantly observed a high tonicity.
2. In blackwater there is occasionally a remarkably low tonicity, in other cases it has the normal value or somewhat raised value as in malaria. The low or normal value in blackwater may be due as we have previously suggested to the faet that the weak corpuscles—those of high tonicity—are destroyed, or it may be due to the fact that the tonicity of the corpuscles, as a whole, is changed after the liberation of hæmoglobin. If hæmoglobinæmia is present (and we have only observed it in two cases) it however will not materially interfere with the reading of the values, as the amount due to this cause can also be determined in a hyper-tonic solution.

The presence again of a yellow serum may cause difficulty.

We may add to these conclusions a third derived from a series of observations on native blood.

3. The tonicity of native blood is often remarkably low: a low value not observed by us in any European blood.

The difference may be as great as 0·04 to 0·06 per cent. salt.

"Blackwater Fever. Cases IX to XVI. Summary and Conclusion." By J. W. W. Stephens, M.D. Cantab., and S. R. Christophers, M.B. Vict. Received November 26, 1900.

I. Record of Cases.

Case IX.—M. Sierra Leone. Blackwater many times previously. Had fever three weeks before present attack, was taking quinine, still feeling unwell continually.

21.3.00. 3 A.M. shivering attack. 6 A.M. t. 100°. Quinine, 1·0 gramme.

22.3.00. 6 A.M. t. normal. Quinine, 0·6 gramme. 5 P.M. t. 101°. Quinine, 0·6 gramme.

23.3.00. 6 A.M. t. normal. Quinine, 0·6 gramme. 10 A.M. rigor. 12.30 P.M. Blackwater. 7 P.M. urine contained hæmoglobin, but not in large amount. Urobilin present.

25.3.00. Urine. No. Hgb. Urobilin present.

Blood examinations :

23.3.00. No parasites. Several leucocytes have fine grains of pigment. A few have golden yellow pigment.

Leucocytes :

17.3.00	Large mononuclear...	22·9 per cent.
	Small ,, ...	2·7 ,,
	Polynuclear...........	73·4 ,,
23.3.00	Large mononuclear...	17 per cent.
	Small ,, ...	3 ,,
	Polynuclear...........	70 ,,
24.3.00	Large mononuclear...	23·6 ,,
	Small ,, ...	6 ,,
	Polynuclear...........	68·6 ,,
25.3.00	Large mononuclear...	19·3 ,,
	Small ,, ...	14·7 ,,
	Polynuclear...........	65·1 ,,
26.3.00	Large mononuclear...	15·2 ,,
	Small ,, ...	8 ,,
	Polynuclear...........	76·7 ,,

Case X.—T. Sierra Leone.

31.3.00. In evening vomited after food ; later took quinine, 0·6 gramme.

1.4.00. Early morning (before 6 A.M.). Blackwater.
Urine. Oxyhæmoglobin. Urobilin absent.
Blood. No parasites. Two pigmented mononuclear leucocytes.

Leucocytes :

10 A.M.	Large mononuclear...	18·75 per cent.
	Small ,, ...	11·4 ,,
	Polynuclear...........	69·85 ,,
3 P.M.	Large mononuclear...	27 ,,
	Small ,, ...	19 ,,
	Polynuclear...........	54 ,,

4 P.M. Hæmoglobinæmia.

2.4.00. 8 A.M. 0·5 gramme quinine hypodermically. 2 P.M. vomiting. 3 P.M. urine, methæmoglobin. No urobilin. t. 98°.

No further examinations made. Death. No autopsy.

Case XI.—E. Lagos. $2\frac{1}{2}$ years in Soudan, 20 months in Lagos.

Much fever during first year and on voyage home. Does not use a mosquito net.

11.7.00. Feeling unwell in morning. 8 A.M. quinine, 0·6 gramme. Got wet through during day. 8 P.M. quinine, 0·6 gramme. 9 P.M. passed a dark urine. No hæmoglobin; no urobilin; no bile pigment.

12.7.00. 4 A.M. darker urine. Methæmoglobin and oxyhæmoglobin (slight). Spleen palpable. Earthy pigmented (jaundiced) condition of skin.

13.7.00. Hæmoglobin well marked.

14.7.00. Hæmoglobin, very weak bands.

Blood examinations:

12.7.00. Parasites. Pigmented leucocytes.

Leucocytes	Large mononuclear ...	21·5 per cent.
	Small ,, ...	16·4 ,,
	Polynuclear	61 ,,

13.7.00. No parasites. Pigmented leucocytes.

Leucocytes	Large mononuclear ...	11·5 per cent.
	Small ,, ...	12 ,,
	Polynuclear	75 ,,

Blood serum rather yellow.

Hæmoglobinæmia doubtful.

Tonicity of blood identical with that of a normal control.

Recovery.

Case XII.—D. Lagos. Blackwater two or three times previously. "Influenza" attack when last home.

17.7.00. Feeling unwell. Temp. raised. Took quinine, two or three 2-grain tabloids. Worse in evening (? more quinine). Rigor in night.

18.7.00. Rigor. Blackwater. Methæmoglobin. No urobilin. Blood. No parasites. No pigment.

Leucocytes	Large mononuclear ...	6·4 per cent.
	Small ,, ...	4·5 ,,
	Polynuclear	89 ,,

19.7.00. Death. No autopsy.

Case XIII.—A. Lagos. 3rd attack of blackwater, last, 1 year 9 months ago. Suffering from slight fever attacks previous to present attack.

10.8.00. Pigmented leucocyte.
18.9.00. Quinine, 0·3 gramme.
19.8.00. 6 P.M. Quinine, 0·3 gramme.
10 P.M. Blackwater.
20.8.00. 7 A.M. t. 103°. Urine. Methæmoglobin. No urobilin. No bile pigment.
5 P.M. t. 103·4°. Jaundice.

Blood examinations :
20.8.00. 7 A.M. No parasites. No pigment.

Leucocytes	Large mononuclear ...	21·5	per cent.
	Small ,, ...	13·5	,,
	Polynuclear	65	,,

Hæmaglobinæmia. Tonicity slightly raised.
5 P.M. Typical pigmented mononuclear leucocyte.

Leucocytes	Large mononuclear ...	21·6	per cent.
	Small ,, ...	17	,,
	Polynuclear	61·3	,,

21.8.00. 5 P.M. t. 102°.

Leucocytes	Large mononuclear ...	18·5	per cent.
	Small ,, ...	17	,,
	Polynuclear	65·5	,,

Death, midnight. No autopsy.

Case XIV.—B. Lagos. Much fever recently. Taking a quinine mixture for last few days (about 0·3 gramme daily).
19.9.00. 5 P.M. t. 102°. 9.45 P.M. blackwater. Quinine, 0·6 gramme (quinine probably after blackwater, but doubtful when). Methæmoglobin. 12 P.M. 0·3 gramme quinine.
20.9.00. 4 A.M. Rigor. t. 106·2°. 2 P.M. no Hgb. No urobilin.

Blood examinations : Extreme anæmia. 10–20 per cent. Hgb. No parasites. No pigment.

Leucocytes	Large mononuclear ...	23	per cent.
	Small ,, ...	23	,,
	Polynuclear	54	,,

Tonicity slightly lowered or normal. Determination very difficult owing to extreme anæmia.

Case XV.—C. s.s. "Sobo." Blackwater in June. Invalided home. Fever on board ship.

27.9.00. Quinine, 0·6—1 gramme. Blackwater some hours after in the evening.

28.9.00. Blood examinations: No parasites. No pigment.

Leucocytes	Large mononuclear...	24·8 per cent.
	Small ,, ...	13·6 ,,
	Polynuclear...........	61·5 ,,

Case XVI.—Cl. Sierra Leone.

4.10.00. Vomiting.

5.10.00. Went to bed. Quinine, 0·6 gramme in evening.

6.10.00. 6 A.M. Quinine, 1·0 gramme. Blackwater.

9 A.M. Quinine, 1·0 gramme.

9 P.M. Urine with small amount of hæmoglobin only.

Blood examinations: No parasites. 2 pigmented mononuclear leucocytes. 1 pigmented polynuclear leucocyte.

Leucocytes	Large mononuclear...	11·6 per cent.
	Small ,, ...	12 ,,
	Polynuclear............	75·5 ,,

7.10.00. Urine. Trace only of Hgb.

Leucocytes	Large mononuclear...	15·5 per cent.
	Small ,, ...	10 ,,
	Polynuclear............	74 ,,

II. Summary.

I. *Relation of Blackwater to Malaria Tropica.*—While it is true that malaria may be very prevalent in a country with little or no blackwater, yet, on the other hand, blackwater fever has never been shown to exist in the absence of malaria, and, on the contrary, it can hardly be a matter of coincidence that in those countries where malaria fever is most malignant, there also blackwater is a scourge.

Further, it is characteristic of their co-existence that the type of malarial fever is the æstivo-autumnal (malignant tertian), or tropical parasite, although very occasionally blackwater and mild tertians have been found together. Thus, in those regions of Africa where malaria and blackwater co-exist, we have the following figures:—

German East Africa ...	89 per cent. malarial cases = tropical parasite (Koch).
British Central Africa...	100 per cent. malaria cases = tropical parasite (Malaria Commission).

Sierra Leone	100 per cent. malaria cases = tropical parasite (Malaria Commission).
Gold Coast	100 per cent. malaria cases = tropical parasite (Malaria Commission).
Lagos	100 per cent. malaria cases = tropical parasite (Malaria Commission).

Further, there is this difference between the malarial fever (æstivo-autumnal) of Italy and that of tropical zones of Africa, that in the latter malaria *prevails throughout the year* without any seasonal intermission. It may be true that malaria is more prevalent in the tropics in the intermediate times between the rains and dry season, but on this point there seems to be a considerable difference of opinion. Statistics are by no means convincing, as at all times many cases of fever are not recorded at all. Yet, whenever we have examined Anopheles from native huts, even in the middle of the dry season, we have found ,no appreciable difference in the number infected, and so Europeans are subject to a constant all-the-year-round infection. As a matter of fact, if we take a number of Europeans, as on a railway, we find that they are more or less constantly suffering from slight fevers, which show no seasonal prevalence. There is, then, no definite intermission in the danger of infection, and this fact, viz., constantly occurring infection, constitutes an important difference from the fevers of temperate climates, where, in the winter, there is a marked decline in infection.

It has been stated that the seasonal prevalence of blackwater bears no relation to that of malaria. And, in fact, statistics have actually been published based upon an indiscriminate compilation of native and European cases, none of which were examined microscopically. If we consider alone the doubtfulness of so-called "fever" in adult natives, such statistics are quite valueless, and it is futile to discuss seriously arguments based thereon as to the seasonal prevalence of malaria and blackwater. Speaking broadly, in most places in tropical Africa there is no very definite seasonal prevalence of either malaria or blackwater.

II. *Premonitory Symptoms in Blackwater.*

In a very large proportion of blackwater cases the patient has for two or three days previously had considerable rises of temperature with vomiting and other symptoms. This initial illness is rarely seen by the medical man, nor are blood examinations made at this time, so that the nature of the illness is often obscure. The character of the temperature curve, however, when obtained, and the almost invariable presence of parasites when a blood examination is made prior to the blackwater, render it very probable that the initial illness which so

commonly occurs before the taking of quinine is *malaria*. Were blackwater to depend alone upon the taking of quinine, one would not expect to find this initial illness so constant a phenomenon.

III. *The Absence of Malarial Parasites in Blackwater.*

A common feature in blackwater cases which are not seen very early is that there is a complete absence of parasites. This is evident from Table I, where in only one case were there parasites present during the blackwater.

If blackwater is a process independent of malaria, then we should expect in those cases where parasites were present that they would follow their usual cycle of development with characteristic temperature curve, superadded to that due, *ex hypothesi*, to the blackwater. But this is contrary to our own experience and that of all observers who have examined the blood microscopically.

Parasites disappear, and do so rapidly: as there is almost always without exception a history of quinine, we think that this will to a large extent account for their disappearance. If we were dealing with an equivalent number of cases of malaria instead of blackwater, as we have shown in an accompanying report, the percentage of cases in which parasites would be found subsequent to the taking of quinine, would be remarkably low. Quinine alone would quite well account for the fact that parasites are so rarely found in blackwater. Whether any other factor is responsible we have no means of saying.

We have previously quoted cases where, although malarial parasites were absent at the time of the blackwater, yet later, under conditions which excluded the possibility of a fresh infection, parasites have reappeared, showing the presence of a malarial infection which at the time of the blackwater was not evident. We had at the time overlooked several instances of this kind recorded by A. Plehn* and F. Plehn.† They are sufficiently important, we consider, to justify us in calling attention to them here.

Examples of Cases where Parasites originally present disappear with the Onset of Blackwater, or, where originally absent, they have appeared later.

1. 4.9. Fever. *Scanty parasites.*
   5.9. Quinine, 1·0 gramme. 2 hours later blackwater. *No parasites.*
   16.9. Weak and feverish. *Parasites.*

* 'Beiträge zur Kentniss von Verlauf und Behandlung der Tropischen Malaria in Kamerun.'

† 'Die Kamerun Küste.'

	17.9.	12 midnight, shivering. 1 A.M., blackwater (? quinine previously).
2.	13.11.	Morning, quinine, 1·0 gramme. 12 noon, rigor. 4.30 P.M., blackwater.
	14.11.	A *single parasite* found.
	22.11.	Numerous parasites.
3.	4.10.	Occasional *parasites.*
	5.10.	Morning, quinine, 1·0 gramme. 12 noon, blackwater.
	6.10.	*No parasites.*
4.	3.9.93.	9 A.M., slight fever. Quinine. Rigor. Blackwater. *Numerous parasites.*
	4.9.93.	Urine clear. 8 A.M., t. 103°. Vomiting. Blackwater. *No parasites.*
	5.9.93.	Convalescent.
	19.9.93.	Slight fever.
	20.9.93.	6 A.M., quinine, 1·0 gramme. 9 A.M., rigor. 10·45 A.M., urine, no Hgb. 12 noon, urine, Hgb. *Numerous parasites.*
	21.9.93.	*No parasites.*
	9.10.93.	Fever.
	10.10.93.	7 A.M. Quinine, 1·5 grammes. 9 A.M. Rigor and blackwater. *Parasites scanty.*
5.	13.11.94.	Many crescents and *parasites.* Quinine, 1·0 gramme. 1 hour later. Rigor and blackwater.
	16.11.94.	*No parasites.*
6.	6.6.84.	Slight fever.
	7.6.94.	6 A.M. Quinine, 1·5 grammes. 8 A.M. Rigor. Blackwater. *Numerous parasites.*
	8.6.94.	Urine clear. 12 noon. t. 102°. Blackwater.
	9.6.94.	No parasites.

In an accompanying report (p. 7) we have shown how commonly ordinary malarial infections, more especially when quinine has been taken, fail to show any parasites. We thus have in undoubted malaria a parallel condition to that in blackwater.

IV. *Relation to Quinine.*

A consideration of the cases recorded by Tomaselli (the first was recorded forty years ago), by Karamitsas, by the Roman school (Marchiafava, Celli, Bignami), by A. Plehn and F. Plehn, and lately by Koch, make it perfectly clear that quinine can under certain conditions induce hæmoglobinuria, and that there are no reasons for believing that tropical hæmoglobinuria (blackwater) in any way differs from the quinine hæmoglobinuria of Europe.

One of Tomaselli's cases :—*

August, 1860. First attack of malaria. Cured by quinine.

1. A month later. A relapse. 1 gramme of quinine. Some hours later—rigor, high fever, vomiting, hæmaturia, and icterus (*blackwater*).
2. During remissions of the fever a larger dose of quinine was again given per rectum owing to the vomiting. The result was as before only more intense (*blackwater*).

   No more quinine was given. Recovery took place in a few days.
3. A month later. Mild fever. A decoction of quinine well borne, but the fever being intense on repeating the dose the result was very different. About 5 hours after the quinine, rigors, hæmaturia, vomiting, icterus (*blackwater*).

   The fever lasted 18 hours. Then defervescence.
4. Fifteen days later. A relapse. 1 gramme quinine sulphate per rectum. 4 hours later—tremors, vomiting, bloody urine, icterus (*blackwater*). Recovery. 2 months of good health.
5. 21st April. Fever with rigor ; vomiting. 23rd. A still more grave paroxysm, so that it was thought necessary to again try quinine. Antimoniate of quinine in decigramme doses every 2 hours. The first dose was given precisely when the malarial paroxysm began to remit. Hardly 2 hours after the first dose had been given there set in rigors, vomiting, hæmaturia, &c. (*blackwater*).
6. 25th April. A fourth febrile paroxysm. Urine now clear. Fearing the fatal effects of a return of another paroxysm, quinine was, in consultation, again ordered as soon as the remission commenced. 50 centigrammes of the bisulphate in a clyster were given 6 A.M. on the 26th. Two hours later the usual train of symptoms—hæmaturia, icterus (*blackwater*), death.

One of Koch's cases :—†

Patient four years in Cameroons. Had blackwater seven times, always following quinine. Patient now in Berlin. From time to time slight fever attacks.

Got wet. Rigor. t. 40·6°. Took two doses of quinine, 0·2 gramme.

Next day, blood examination negative.

* 'La intossicazione chinica e l'infezione malarica' (Comm. Salvatore Tomaselli).

† Koch, 'Über Schwarzwasserfieber (Hæmoglobinurie),' s. 316.

Some weeks later, fever attack. By instruction had taken no quinine. Blood examination positive. (Large pigmented tertians.)

Patient advised to take methylene blue and no quinine, but after a few days he consulted another physician, who ordered him quinine.

Scarcely had he taken the quinine when a violent attack of *blackwater* ensued. Brought into hospital.

2nd. (4 × 0·1) gramme quinine—a few hours—*blackwater*. t. 40·5°. No parasites.

6th. (4 × 0·1) gramme quinine—a few hours—*blackwater*. t. 41·0 . No parasites.

14th. (4 × 0·1) gramme quinine—a few hours—*blackwater*. t. 39·5 . No parasites.

24th. (4 × 0·1) gramme quinine—a few hours—*blackwater*. t. 41·5°. No parasites.

It would appear from the criticisms made on Koch by many writers that they have not taken the trouble to acquaint themselves at first hand with his writings, for views are constantly attributed to him which certainly are not to be found in his writings; and, further, there seems to be a general impression, at least among English writers, that Koch was the first and only person to enunciate the quinine hypothesis. Such an impression, a knowledge of the literature of blackwater would have removed. A study of 200 cases published by competent observers, and our own cases, has convinced us of the causal connection between quinine and blackwater.

Among our own cases we have not met with one in which quinine could be excluded beyond all doubt, but, on the contrary, the blackwater followed more or less closely after the quinine.

Why quinine at one time can produce blackwater and a few hours or days later not, it is impossible in the present state of our knowledge to say. We can only expect that a solution will be forthcoming when toxic hæmoglobinurias generally are more closely investigated, and when some new light is thrown upon such an obscure disease as the paroxysmal hæmoglobinuria of temperate climates.

V. *Evidence of Malaria in Blackwater.*

We have previously seen that, in a large proportion of cases of blackwater, parasites are not to be found by the most careful search. This, indeed, has led some authors to conclude that many cases of blackwater occur without any accompanying or closely-preceding malarial infection.

A study of cases, however, of undoubted malaria in which quinine

has been administered leads us to consider that parasites in the peripheral blood are not necessarily present even in undoubted cases of malaria, and that their absence in blackwater may be quite compatible with a severe malarial infection. We therefore examined the blood in our cases of blackwater with a view to determine whether or no they showed the less striking evidences of malaria such as we still find in ordinary cases of malaria treated by quinine, *i.e.*, the presence of pigmented leucocytes and an increase in the large mononuclear leucocytes. We have pointed out elsewhere that in cases where the autopsy revealed severe malarial infection, pigmented leucocytes have been extremely rare in the peripheral blood, and that it is often only at certain times that the increase in large mononuclear leucocytes is to be detected. We do not, then, expect in every case of malaria to find pigmented leucocytes in abundance, or to find without repeated examination a marked leucocytic variation. In blackwater, also, if it is malarial in nature, we should not expect in every case gross evidence of malarial infection, more especially as blackwater for the most part occurs in those who have been some years in the tropics and who suffer from modified attacks of malaria rather than severe attacks.

In the accompanying table (p. 24) a tabular arrangement of our sixteen cases of blackwater is given showing the evidence of malarial infection at the time of the attack or immediately prior to it. It will be seen that in one case (Case 3) blackwater came on in the course of an ordinary severe attack of malaria, that with the onset of blackwater there was a coincident disappearance of parasites. In Case 11, which was seen earlier in the disease than usual, parasites were at first present, but later disappeared. In Cases 2, 4, 5, 8, 9, 10, 13, 16, at least one typical crowded pigmented leucocyte was found, and in several cases these were common. In Cases 14, 15, 17, although neither parasites nor pigmented leucocytes were seen, yet the number of large mononuclear leucocytes was in every case over 20 per cent., a percentage which we have in Table II shown is very strong evidence of malarial infection. One case only (Case 12) has failed to yield evidence of malarial infection, and in this case our investigation was confined to a single blood examination, and hampered by the fact that the only films available were badly made. In Case 1 fresh films only were examined, and as pigmented leucocytes were not especially searched for, and as the leucocytes were not counted, we have omitted it from the list.

In 16 cases of blackwater we have, then, evidence of malarial infection in 15, *i.e.*, in 93·8 per cent. As in Koch's cases, parasites themselves were found in over 40 per cent., we think it highly probable that, had attention been paid to pigmented leucocytes and the proportion of leucocytes, his cases would have shown an equally high percentage of malarial infection. Two post-mortems in which no

pigment was found are certainly against this view, but we would point out that in a case of blackwater described by Dr. Thin, although there was only extremely scanty pigment in the spleen, yet there were sporulating parasites in the brain; also that in these cases of Koch death occurred on the 5th and 10th day respectively after the onset of the blackwater, possibly long enough for the pigment from a mild attack to disappear. In five post-mortems of our own we have found abundant pigment occurring in such a way as to make it certain that it arose from very recent attacks coincident with the onset of the blackwater. As no parasites were found (except in one case where numbers of developing gametes were found) it would appear that the disappearance of parasites from the peripheral blood is often further followed by a disappearance of parasites from the internal organs.

In our own cases, then, we have five autopsies showing recent malarial infection, and 93·8 per cent. of our cases showing undoubted evidence of malarial infection in the peripheral blood.

It has been urged that the occasional presence of parasites in blackwater is accidental and dependent on the fact that the subject of blackwater is living in a highly malarious country.

A considerable number (44) of Europeans living in the tropics were therefore examined by us for evidence of malarial infection, viz., either parasites or pigmented leucocytes or an increase in the mononuclear leucocytes. The result of this examination is given in Table II. It will be seen that most of the communities chosen are those especially liable to malarial fever, and indeed among the Roman Catholic community mosquito nets are rarely used, whilst on both the Lagos and Sierra Leone railways malarial infection is most rife. Yet in the blood of these individuals we find parasites with the greatest rareness, nor are pigmented leucocytes much more frequent. A certain number show a percentage of large mononuclear leucocytes above normal, but most of these do not reach as high a value as in most of the blackwater cases, the blood examination having often been no doubt too late in convalescence to show marked percentages. Those showing parasites or pigmented leucocytes are under 10 per cent., whilst including those with even a poorly-marked mononuclear increase only 20 per cent. show evidence of malarial infection.

It is thus abundantly evident that the malarial infection demonstrable in over 90 per cent. of blackwater cases is not dependent on the accidental occurrence of malaria, but must be a causal connection.

We must accordingly assign to the hæmoglobinuria of the tropics a malarial origin, though recognising that it is by no means a mere malarial attack of extreme severity.

Table I.—To show the occurrence of Malarial Infection in Blackwater.

Cases.	Parasites.	Pigmented leucocytes.	Autopsy.	Large mononuclear leucocytes.	Small mononuclear leucocytes.	Polymorphonuclear leucocytes.	Proof of malarial infection at time.	Parasites present in peripheral blood.	Remarks.
2*	—	pig. leucs.	much pigment.	22·7	14·6	60·7	Yes	No	
3*	numerous parasites	" "	" "	55·9	—	43·0	"	Yes	22.5.99. Before onset of blackwater.
		" "	—	19·3	—	80·0		No	24.5.99. Shortly after onset.
4*	3 crescents	" "	—	48·8	8·4	41·6	"	"	
5*	—	—	—	30·6	7·8	61·6	"	"	
6*	—	—	much pigment.	—	—	—	"	—	Post-mortems only.
7*	—	—	much pigment.	—	—	—	"	—	Post-mortem only.
8*	—	pig. leucs.	much pigment.	12·0	7·0	80·0	"	No	
9	—	" "	—	23·6	6·0	68·6	"	"	
10	—	" "	—	27·0	19·0	54·0	"	"	
11	parasites	" "	—	21·5	16·4	61·0	"	Yes	12.7.00. Case seen earlier than usual.
		" "	—	11·5	12·0	75·0		No	13.7.00. Blackwater still present.
12	—	—	—	6·4	4·5	89·0	No	"	Only a single blood examination made.
13	—	pig. leucs.	—	21·0	13·5	65·0	Yes	"	
14	—	—	—	23·0	23·0	54·0	"	"	
15	—	—	—	24·0	13·6	61·5	"	"	
16	—	pig. leucs.	—	12·7	10·5	77·0	"	"	6.10.00.
				15·5	·10·5	74·0		"	7.10.00.
17	—	—	—	22·7	12·6	64·0	"	"	Convalescent, 6 days.

* Note.—See the First Report to the Malaria Committee. Case I is not included on account of the insufficiency of the examination.

Table II.—To show the occurrence of Malarial Infection in Europeans taken at random, more especially from Communities suffering much from Malaria.

		Parasites.	Pigmented leucocytes.	Large mononuclear leucocytes.	Small mononuclear leucocytes.	Polymorphonuclear leucocytes.	Eosinophyl leucocytes.	Proof of existing or very recent malarial infection.	Remarks.
Lagos R. Catholic fathers	1	—	—	12 ·3	17 ·6	58 ·6	11 ·3	No	
	2	—	—	16	20 ·6	61 ·6	1 ·6	?	
	3	—	—	18 ·6	19 ·8	61 ·2	2 ·4	Yes	
	4	—	—	13	19 ·5	61 ·5	6	No	
	5	—	—	10 ·6	25	62	2 ·3	,,	
	6	—	—	19 ·5	19	59 ·2	2 ·2	Yes	Slight fever at time.
	7	—	—	15	8	74 ·6	2 ·3	No	Fever at time.
Lagos R. Catholic sisters.	8	—	—	13 ·3	17 ·6	66 ·3	2 ·6	,,	
	9	—	—	11 ·2	23 ·2	64 ·5	1	,,	
	10	—	pig. leuc.	10 ·6	14 ·3	67 ·6	7	Yes	
	11	—	—	10 ·6	29	57 ·3	3	No	
	12	Crescent	—	10 ·5	17 ·5	71 ·5	0 ·5	Yes	
	13	—	—	13 ·5	23	62 ·5	0 ·75	No	
	14	—	—	13	34	51 ·5	1 ·5	,,	
	15	—	—	20	15 ·5	61	3 ·5	Yes	
	16	—	—	13 ·2	21 ·7	61 ·7	3 ·2	No	
Lagos merchants' clerks.	17	—	—	7	18 ·5	74	0 ·5	,,	
	18	—	—	14 ·5	21	61 ·5	3	,,	
	19	—	—	13	6 ·75	60 ·7	9 ·5	,,	
	20	—	—	14 ·5	24 ·5	56	5	,,	
	21	—	—	10	12 ·7	73	4 ·3	,,	

Table II.—*continued*

		Parasites.	Pigmented leucocytes.	Large mononuclear leucocytes.	Small mononuclear leucocytes.	Polymorphonuclear leucocytes.	Eosinophyl leucocytes.	Proof of existing or very recent malarial infection.	Remarks.
Lagos Government railway men	22	—	—	11 ·3	20 ·3	67	1 ·3	No	
	23	—	—	13·6	39 ·3	46	1	,,	
	24	—	—	13	20 ·5	58	3 ·5	,,	
	25	—	—	7 ·6	15 ·3	76 ·3	0 ·6	,,	
	26	—	—	18	26 ·5	53	2 ·5	Yes	
	27	—	pig. leuc.	12	19	66 ·5	2 ·5	,,	Fever at time and previously.
	28	Crescents	—	26 ·6	19	54	0 ·5	,,	
	29	—	—	12	31	51	6	No	
	30	—	—	12 ·5	22	65 ·5	—	,,	
	31	—	—	12 ·7	11	74 ·6	2	,,	
Sierra Leone railway men	32	—	—	11 ·3	17	68 ·6	3	,,	
	33	—	—	20 ·3	24 ·3	52 ·6	2 ·6	Yes	Temperature 104° day before quinine.
	34	—	—	14	18 ·3	67 ·3	0 ·3	No	
	35	—	—	13	15	70 ·6	1 ·3	,,	
	36	—	—	15	20·8	60	4 ·1	,,	
	37	—	—	10 ·5	14 ·5	73	1 ·5	,,	
	38	—	—	11	13	72	4	,,	
Government officials	39	—	—	9 ·6	11 ·3	75 ·3	3 ·6	,,	
	40	—	—	12 ·6	16 ·3	50 ·3	11	,,	
	41	—	—	10	21 ·3	66 ·6	2	,,	
	42	—	—	10·6	11	78 ·3	—	,,	
	43	—	—	13	13 ·1	65. 4	8 ·5	,,	
	44	—	—	10 ·2	16 ·5	69	5 ·2	,,	

III. *Conclusion.*

1. That blackwater is malarial in origin, yet cannot be considered as an attack of malaria.
2. That quinine is, in the great majority of cases, the proximate cause.
3. That there is not a single fact in evidence of a special parasite being the cause of blackwater. Blackwater more closely resembles paroxysmal hæmoglobinuria, and possibly hæmoglobinuria in horses, than Texas fever.

Protection from malaria, then, would diminish the chances of blackwater fever, and measures directed against malaria would, if successful, tend to diminish the amount of blackwater, which at present is pre-eminently the cause of death among Europeans in tropical Africa.

Malaria is, we believe, a preventible and avoidable disease; consequently the European in the tropics, who thinks it worth while to avoid malaria, will have little fear of being attacked by blackwater fever.

We cannot conclude our report without acknowledging our indebtedness to the medical officers of the colonies we have visited, to Dr. Gray, Zomba; Dr. Kerr-Cross, Blantyre; Dr. Prout, Sierra Leone; Dr. Knight, Accra; Dr. Strachan, Dr. Pickels, and Dr. Best, Lagos. Also to the medical officers on the Sierra Leone and Lagos railways, Dr. Leach, Dr. Rowlands, and Dr. McGahey.

We have especially to thank Dr. McVicar, Blantyre; Dr. Berkeley, Freetown; Dr. Knight, Accra, and Dr. Hopkins, Lagos, for much help and for much trouble undertaken on our account. Also Dr. Scott and Dr. Elmslie, British Central Africa, and Dr. Todd, late of Umtali, for specimens of blackwater cases.

REPORTS, &c., FROM Dr. C. W. DANIELS, EAST AFRICA.

"Some Observations on the Common Anopheles of British Central Africa, the Haunts and Habits of their Larvæ during the Dry Season, 1899." By C. W. Daniels, M.B. Received January 8, 1900.

These observations were made in, and refer only to the Dry Season, April to October. A further series of observations will be required for the Wet Season.

The commonest and most widely distributed Anopheles is a small dark one* with legs of a uniform colour and two light bands on the palpi. It is found at all heights from 4200 feet down to 200 feet above the sea-level. It is also met with all round the Lake Nyassa and down the Shiré River for at least 150 miles. This represents the limit of my observations. In some of these places it is so numerous as to be a pest. In others it is only found with difficulty.

Under experimental conditions it will only lay its eggs on still water. The motion of the surface of the water produced by the wind is quite sufficient to prevent the deposit of eggs.

The eggs are laid on the surface of the water in little clumps. They are separate and lie horizontally on the water. They readily adhere to any solid body with which they are brought in contact. As a consequence of this adhesiveness they are often found adhering to the sides of the vessel containing them, especially if the water has been disturbed by wind or movement. It is probably on account of this property that they are so difficult to find under natural conditions.

The eggs hatch in two or three days. If allowed to dry, or if completely immersed for half an hour, they will not hatch.

The larvæ are very small, and difficult to see for the first two or three weeks. Their habit varies under the different conditions met with, but they usually are easily found in small numbers.

To determine their haunts in the Highlands, I have examined all the waters in Blantyre and the immediate neighbourhood at the end of the dry season, with the following results.

The larvæ are found constantly in the swamps or shallow pools marking the outlets of the springs which form the sources of the

* Since identified by Mr. F. V. Theobald as *Anopheles funestus.*

numerous streams. These pools are usually overgrown with grass. The larvæ are of all ages, from the quite young to the pupal forms. In the streams arising from these springs, larvæ are also constantly found in places where the current is slight, particularly where the water is screened from sun and wind by overhanging banks or grass. When such a stream reaches a level portion and spreads into a pool or swamp, the larvæ are often abundant, but not if the water is stagnant or markedly peaty.

The larvæ are of different ages, but I have not observed very young forms in the streams. This suggests that the larvæ in these situations have been carried down from the springs; but as they are found day after day in the same places and sometimes as pupæ, these streams, if they are not actually the breeding grounds, at least distribute the mosquitoes and allow the further development to take place.

Several of these streams join to form a small rivulet, the Mudi, which is in places several yards wide. This I have followed for some three miles, and all along at points have found these larvæ.

The larvæ are also found in irrigation trenches used for gardening purposes, under similar conditions to those found in streams.

In none of these springs, streams, or trenches did I find any fish, so these must be rare. The natives say there are some, but that they are not abundant in the upper reaches.

These breeding grounds abound in the Highlands, even after prolonged dry weather. In an area of about two square miles I found no fewer than eleven of these springs, and I know of four others now dry which were active early in the dry season, and from the lie of the ground it is certain that there were many more in the first months of the dry weather.

On leaving the Highlands true rivers are found. These run into the Shiré, which rises from Lake Nyassa. The Shiré and these rivers swarm with small and large fish.

The Shiré, as traced from the lake, shows the conditions under which larvæ are found in waters swarming with fish. The river is the main if not the only breeding ground of the mosquitoes, as they are found at no great distance from the banks, and their prevalence varies with the favourable nature or otherwise of the conditions in the river for the existence of the larvæ.

The Shiré River on leaving the lake runs through low, sandy, alluvial land. The banks are usually low, swampy, and covered with rank grass and reeds. Any holes, such as hippopotamus tracks, are filled with peaty water. In these holes I have never found the larvæ, and the water, if added to that in which larvæ are growing, will speedily kill them.

From the edge of the banks grows a short grass which extends right out into the stream, sometimes for 20 yards or more. This grass is

supported by a close meshwork of floating but submerged roots. Masses of this grass may become detached from the bank and form floating islands. Above the false bottom formed by the close meshwork of floating roots is shallow water, into which fish will not have ready access; in this water the Anopheles larvæ, of all ages, are found. They are not found in great numbers, but are found constantly, and are more numerous near the bank. Where this grass abounds the mosquitoes are numerous, even after months of dry weather, when the river is at its lowest, and all other water is gone.

Lower down, the Upper Shiré expands into a shallow lake, Lake Pamalombi, covered with tall reeds in great part. The floating grass is not abundant. In the wet season mosquitoes are very abundant, but are not very plentiful at the end of the dry season.

Below this lake there is little grass with floating roots; its place seems to be taken by a coarser grass rooted in the bottom, but also throwing out plenty of aqueous roots, so that a meshwork, though not very close, is formed. I found larvæ amongst this in places where it was thick. In the later part of the dry season the mosquitoes here are far less numerous than in the early part, when there are extensive swamps.

So far this Upper Shiré is navigable from the lake. It is about seventy miles long. The next portion, the Middle Shiré, is a series of rapids seventy miles long with a total fall of some 1200 feet. The current varies greatly. In some places the stream is slack enough to allow of a ferry, and in one of these places there was abundance of this fixed grass. Here the Anopheles were found. The same grass was seen in patches all along the river. In one part the river flows through deep rocky gorges with great rapidity; we camped here for the night, but found no mosquitoes.

On the west bank, at the time I was there, there were only two rivers running into the Shiré; in one of them there was much fixed grass, and on its banks there were plenty of Anopheles. The other had a rocky bed, and I am informed that there were no mosquitoes there.

Below these rapids is the Lower Shiré, navigable from the sea. The fixed grass was very abundant here, but the Anopheles were not very abundant, though both the larvæ and adults were found without difficulty. The climate is very different on the Lower river and much hotter. Culices of several species, including a large yellow one which carries the *Filaria nocturna*, abound.

The only other important water is Lake Nyassa, 1540 feet above the sea and 350 miles long. No mosquitoes are found in the open. The banks at the places I visited were fringed with reeds. There was no floating grass and very little grass growing into the lake. Mosquitoes are rare in many places on the lake shore.

In the lake itself I found Anopheles in one place only.* This was in a sheltered bay where the reeds extended for a long distance out. The larvæ were not found among the reeds, but just at the edge of the lake, where grass was growing and a kind of small water-lily.

At this time the streams running into the lake were in many cases dry or reduced to a series of stagnant water holes, in which no larvæ of Anopheles were found. In other places there was a series of water holes with a small stream connecting them ; in some of these the larvæ were found. Replacing the end of the stream in some places was a small pool at the lake level, but separated from it by a sandy bar. In these pools the larvæ were constant.

The different situations in which the larvæ are found under these diverse conditions have points in common. In all, the water is fresh, and kept so. It is more or less permanent. Fish are scarce, or the larvæ are protected from them.

I have at times found the larvæ in small pools without any connection with other water, and the larvæ were sometimes over two weeks old. In some such puddles, which I was able to watch, the larvæ soon died or the puddle dried up. In the last case the larvæ were not restored by adding water. As the shortest period I have observed for the larvæ to reach maturity has been thirty-two days, the chances of such larvæ reaching maturity in the dry season must be very small. Even pools large enough to contain water all through the dry season after a few months become stagnant, and larvæ are not found in them.

Observations made on larvæ under artificial conditions explain in the main the reasons for the natural distribution. The constant motion of the lake would be unfavourable for the laying of eggs. The eggs when laid would be carried by the waves and attached either so high that they would be dried, or so low that they would be submerged, and therefore not hatched.

The length of time required for the growth of the larvæ with their susceptibility to stagnation explains the need of some permanent fresh-water supply. In captivity fresh water has to be added almost daily, or they will often die.

There is no difficulty in understanding how the larvæ are able to exist in running water. If larvæ be placed in an open vessel when there is a strong wind blowing, the water is put into rapid rotation ; but the larvæ, without any apparent motion, are able to maintain their position, adhering by their tails to the side of the vessel. If attached to a floating object it will rotate with the water, and the larvæ with it, without any signs of inconvenience. They are also able to move against a strong current for short distances.

* Subsequently, in 1900, I found Anopheles larvæ in many similar places at the Lake edge.

The conditions inimical to their existence are stagnation, putrefaction, or peatiness of the water. Their most important natural enemies are small fish. In addition, the larvæ, either of the same or a different species, will at times devour a younger one. If Cyclops are very numerous they will destroy the very young, but not the older larvæ.

There is one condition under which I have uniformly failed to find these larvæ, though those of Culices may be found, and that is in wells, unless the surface of the water is flush with the ground. The native wells are mere holes dug in the ground at or below a spring. In the dry weather the water-level is below the surface of the ground, and only Culices, if any larvæ at all, are found. The European wells are brick and are often covered. It is exceptional to find any larvæ at all in these, and those are not Anopheles. To kill the larvæ it is not necessary to dry them. If the superjacent water be poured off, they will not live more than a few hours in the liquid mud. Advantage might be taken of this to kill the larvæ in irrigation trenches, as diverting the water for a few hours two or three times a month would probably kill off the larvæ in it.

The breeding grounds in the wet season will have to be a specia study, but with our present knowledge it is probable that in the Highlands they will be confined to the springs, but those will be both more extensive and more numerous.

In the river the floating grass will be little affected, but extensive areas near the river will be flooded, and there the larvæ will be able to live during, and for some time after, the wet season, till the water becomes peaty or stagnant.

The adult mosquito bites mainly at night, but occasionally in the day. Unlike many of the Culices it does not leave the house in the day, but will be found at dawn near the bed. When disturbed it flies upwards, so that by the time a room is swept out, or a free current of air is established, it will be found high up on the wall only.

Prophylaxis.—In a well-watered country any complete extinction of the species would appear to be impracticable.

In any given area they might be exterminated or much reduced. This will be costly in such sites as Blantyre, with numerous springs and rivulets.

Probably the best means would be the erection of wells with a clear pipe or brick overflow below the surface of the ground wherever there is a spring. The streams themselves should have their banks kept clear of brush and long grass, and places where the stream spreads out into a marsh have a graded drain through them. In the rivers the floating grass should be detached for a considerable distance above and below any settlement early in the dry season. If the long grass and reeds were cut down and the banks kept clean, the period during which the mosquitoes are prevalent would be much reduced.

Some of these measures are required on other grounds. In the bush surrounding the sources of the rivers and streams is much filth, as it is used by the natives as a latrine.

More wells are required, as the water supply is inadequate unless much fouled river water is used.

The houses should be better ventilated, and top-ventilation introduced to give the mosquitoes fewer resting places in the houses. The narrow beds and mosquito curtains allow the mosquitoes to bite any part of the body which comes in contact with the net. In the morning numerous mosquitoes gorged with fresh blood are usually found on the outside of the net. The small mosquito-proof room with the bed inside is much safer.

Larvæ of other Anopheles are much rarer, but I have found them in the springs, and the streams running from them, so that they seem to have similar habitats.

"Distribution and Breeding Grounds of Anopheles in British Central Africa." By C. W. DANIELS, M.B. Received June 7, 1900.

In continuation of my report on the breeding grounds of Anopheles for the Dry Season, April–October, 1899, I have the honour to report as follows for the Wet Season, October 1899–March, 1900:—

The observations for this second period are in the main confirmatory, and in parts explanatory, of the observations in the previous dry season.

2. The observations were made in the Shiré Highlands at Blantyre, my headquarters during some portion of each month, and Zomba, in January, February, and March.

On the Upper Shiré (lake level) November, December, and March.

On the Lower river in February.

3. The increase in the number of mosquitoes has not been very marked at most places, except at Zomba. With the first onset of the rains there was an immediate decided increase in the number of mosquitoes infesting the houses. This, I think, was probably due to the mosquitoes seeking a more secure shelter than that afforded by grass, &c. This increase was not maintained; on the contrary, at Matope (Upper river) in November and December, fewer mosquitoes were found in the house than in May or September, when I had been there before.

The Breeding Grounds.

4. The wet season commenced unusually early (in October), with days of heavy rain alternating with periods of rainless weather. This weather continued till near the end of November. During December,

January, and the early part of February the rains were more continuous, and the periods of rainless weather shorter.

Since then the periods of fine weather have again been longer. The attached table shows the amount and distribution of the rains during the period under review. Perhaps the clearest way of indicating the effect of this season is to take as an illustration a single small drainage area. The one nearest is selected for description, as that is the one most constantly under observation, but the results have been confirmed by frequent periodical examination of other known breeding places in the immediate neighbourhood, and by numerous isolated examinations over 100 miles of road in the Shiré Highlands. The place is some distance from the mountains, and in gently undulating country. Down the hollow, the water during rains pours into the Mudi (the small river separating Mandala and the hospital from Blantyre and the Scotch mission). The position of this stream is marked by the belt of trees in the photograph*. The height of the ridges surrounding this hollow marks the watershed between this and another small water system. In the views taken, this adjoining water system runs nearly at right angles, though the water from it is also poured into the Mudi. About half way down the gully is a spring permanent all the year round, and round about it a swamp. This swamp, as is usual, is overgrown with tall blue grass, which here and elsewhere indicates permanently wet soil. It is further indicated in the photo by the natives who are standing just above it. From this spring a small stream runs to the Mudi, spreading out in places into shallow swamps, and in others overgrown and blocked with grass.

About the source of this spring and in places in its course where it spreads into shallow swamps, or in dry weather is running very slowly along the grassy edges, Anopheles larvæ were found constantly, both at the end of the dry season and all through the wet.

Above this permanent spring is a natural cutting dry from May to October, except during and immediately after showers.

In the early part of the wet season after each period of rain it soon dried up, in each spell of dry weather leaving a few small pools in which, up to late in November, no Anopheles larvæ were found. Towards the middle of December, even in dry days, water was to be found oozing from the sides of the cutting in places, and consequently the channel never became dry.

In many parts of the course of this cutting grass had grown, and in level portions shallow pools were formed, and from the end of December Anopheles larvæ were found constantly in such places.

In this valley were several deep pits left in brick making, and one of them was deep enough to contain water permanently throughout this

* Not reproduced.

season. These pits have all red clay walls, and usually little vegetation; they are common throughout the Protectorate, as most of the houses are built of brick, but in none of them have I found Anopheles larvæ.

Towards the head of the valley there is a swampy area much trodden by cattle; in their tracks water collects, and will withstand several days dry weather, but no Anopheles larvæ were found in them. On the left-hand side of the valley, looking down it, is the public road. On each side of this is a cutting to carry off the water in rainy weather. With constant rains they are scoured out, and after two or three days dry weather they are dry. No Anopheles larvæ were found in them.

On the right-hand side of the road there is a small extent of flat land; on this ephemeral puddles only form, and in them no larvæ were found. There is also a cattle pond formed in red clay like the brickfield ponds; in this Culices in abundance, but no Anopheles, were present.

This valley fairly represents the usual conditions in the Shiré Highlands in the neighbourhood of Blantyre; and in the area of about two square miles, including Blantyre township, the Blantyre mission, Mandala, and the Blantyre hospital, there are some fourteen similar small valleys. In some there are two springs, in others the slope from the springs is steeper, and larvæ are only found near the springs, and in others the springs dry up before the end of the dry season.

The Anopheles larvæ found were not all of one species. In the valley I have taken as an example, larvæ of all the five Anopheles found in these Highlands were found at one time or another. In no other valley have I found the same number, but two or three species were commonly found together, and sometimes four. As the associated species differed at different times and in different places, I consider that all the Highland Anopheles have similar breeding places, and that the five were found in this valley was probably due to the more frequent examinations made.

The commonest larvæ found were that of the so-called "small black" Anopheles.

In my report on the dry season I pointed out that the Mudi itself, though a running stream, contained these larvæ.

With the onset of the rains this stream was converted into a muddy torrent. At first, with each period of dry weather, the river fell rapidly and became clear, and the Anopheles were again found in the same or similar sheltered positions to those of the dry season. This observation was repeated in several places, both on the Mudi and in other streams, in several of the dry periods in the first six weeks of the rains, and leads me to believe that the larvæ are washed down from the springs to such situations, rather than that they have been actually bred there.

The importance of this difference will be better considered in connection with irrigation trenches.

By the middle of December the level of the stream was permanently decidedly raised, and the force of the current uniformly great. In spells of dry weather the water became clear, but the level never low. From that time onward larvæ were never found in the stream, nor in any of the other permanent clear streams I visited.

In Zomba the conditions are different, though the general principles are the same. Zomba is situated on the south-western slope of a mountainous plateau (Zomba mountain), some 6000 feet high: it is about the same level as Blantyre (3200 feet high), and a few hundred feet above the table land (Shiré Highland) to the south. There are numerous springs, but instead of being in definite valleys they are rather extensive swampy areas, probably dependent on subjacent rocky fissures. In these areas Anopheles larvæ were found.

The natural streams running from them were free from larvæ, and the slope is so steep that it is improbable that larvæ could remain in them.

For drainage and irrigation purposes an extensive network of trenches had been cut. Many of these are nearly horizontal, and others have been neglected and allowed to become blocked, overgrown with grass, or leaky, so as to form small swampy areas.

In others, again, the area to be irrigated is too extensive for the water supplied, so that in portions the water is practically still even in heavy rains. In all these classes of situations, Anopheles larvæ were found.

There was a marked difference between irrigation trenches in which the water was derived from a clear running stream, and in those in which the water was the drainage of an Anopheles-bearing swamp. In the former, Anopheles larvæ were only found where the conditions described were present in a gross form; in the latter, when there was sufficient pause in the rains for the water to become clear, they were found in any place where the current was slack.

This affords a further and more conclusive reason for considering the larvæ in trenches to be in part carried down from the true breeding grounds. They are washed down by the rains and accumulate in suitable places. In trenches—as roadside ones, where the water soon dries up—Anopheles are sometimes found, in and only in the vicinity of an Anopheles swamp.

On the Zomba plateau itself are a few houses, used as a sanatorium, at a level a little over 5000 feet. This portion of the plateau is gently undulating, and in one place very similar to the places round Blantyre I found Anopheles larvæ. They were found with difficulty and in very small numbers, though the local conditions were favourable. It is therefore probable that this height, is, in this latitude, near the limit suitable for the breeding of these mosquitoes.

In the broader flat valleys in the Highlands there are in the wet season extensive swamps; in these, Anopheles larvæ are rarely met with.

I had anticipated finding Anopheles larvæ in open puddles during the wet season. In only one instanee did I find them, and that was in a shallow excavation not penetrating through the black soil, and near a stream, but not supplied by it or by any other stream. In this, numerous Anopheles larvæ and some Anopheles pupæ were found, but this was after a month with hardly a rainless day, and in low land on the low banks of a stream. On the Upper and Lower rivers (Shiré) Anopheles larvæ were found, as during the dry season (among the grass growing in shallow water, and in that on the floating grass prevalent in the Upper Shiré above Lake Pamalombi).

The river was considerably higher and the current stronger, in one place (Chikwawa) said to be three miles an hour.

In the marshy ground where in the dry season the water was stagnant or peaty, the abundant rains had in places reduced this condition, but in no instance did I succeed in finding Anopheles larvæ. Frequent examinations were made in many different places with negative results, but considering the extent of these swampy areas during the wet season, I cannot consider my negative results as conclusive. In some parts of them, at least, the conditions must be favourable for their development.

On the Upper Shiré only one Anopheles (the "small black") has been found by me.

On the Lower river the "small black" is also found, and in addition three others different from those in the Highlands, and in the river there three kinds of larvæ were found—those of the "small black" and two other kinds—which, however, I failed to rear. It is therefore probable that in the Lower river the different Anopheles have similar breeding grounds as is the case in the Highlands. The lake I was unable to visit.

I have paid particular attention to all kinds of puddles during this wet season. The instance given above is the only one I have met of larvæ being found.

In some instances, in small grass-grown hollows which only overflow with heavy rains, but into which water runs with slight ones, larvæ were found during the time when there were few successions of dry days. Such places are rare.

I subjoin a table showing the places in which larvæ have been found in the Protectorate in the year under review.

To a large extent, not only each country and district but even locality differs in details. The slope of the ground, its nature and permeability, will largely determine where water, suitable for the breeding of these mosquitoes, will be found, and whilst in British

Table showing Rainfall and Distribution of Rains during the Year in Two Places in Districts Nos. 2 and 3. The figures for Fort Johnston are for the previous Year; those for 1899—1900 were not obtainable.

Zomba. Shiré Highlands.

Month.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Rainfall for month	9·75	2·7	0·51	0·07	0·1	0·12	2·23	13·40	7·79	15·94	2·19	5·76
Number of days on which rain fell	18	12	6	3	1	1	4	19	21	25	11	12
Longest period without rain	4 days	7 days	19 days	28 days	30 days	29 days	12 days	5 days	4 days	Under 2 days	6 days	15 days

Fort Johnston, Upper Shiré (Lake Level).

Month.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Rainfall for month	0·38	*p*	0·2	0	0·12	0·05	0·38	1·73	8·66	7·54	8·68	6·89
Number of days on which rain fell	3	1	2	0	1	1	1	9	14	22	14	17
Longest period without rain	10 days	27 days	28 days	31 days	20 days	29 days	30 days	8 days	4 days	4 days	3 days	4 days

There were 79 days (consecutive) without a shower in these three months.

Description of Places.	Dry season, July to October.		Onset of rains, October to December. Oct.	Nov.	Dec.	Wet season, continuous. Jan.	Feb.	Mar.	Drying-up season, April to June. April.	May.	June.
The Lake Shore—											
A. Clear, or only fringed with reeds.	0	0	0					0		0	0
B. Behind sand bars separated from lake.	+	+									+
C. Among thick vegetation	+										
Shiré River—											
A. Open water	0	0	0	0	0		0	0	0		0
B. When sheltered by grass...	+	+	+	+	+		+	+	+		+
Swamps in Plains	0	0	0	0	0	+	+	0	0		0
Large Streams (*Mudi, &c.*)	+	+	+	+	0	0	0	0	0		
Slow Small Streams—											
With slow current, or blocked in places.	+	+	+	+	+	+	+	+	+		
Irrigation Trenches	+	+	+	+	+	+	+	+	+		
Springs—											
Permanent all the year round..	+	+	+	+	+	+	+	+	+	+	+
Permanent in the wet season and early dry season.					+	+	+	+	+	+	
Puddles—											
Permanent in wet season......			0	0	0	+	+	0	+ on the Zambesi		
Native Wells	Very rare, and only when the water level was nearly that of surrounding ground.										
European Wells...............	None found at any time.										

0 indicate that larvæ were not found. + indicates that larvæ were found. *No entry* that no sufficient examination was made; in some cases because none was possible; in others, as in April and May, because I did not then know in what places to look.

Central Africa a porous, rocky, or sandy soil, and low-level subsoil water, prevents puddles being an important breeding ground except under exceptional circumstances; under other local conditions, even with similar meteorological factors, they may be the leading one.

The obvious presence of Algæ is no necessity; on the contrary, if abundant, Anopheles larvæ are rarely found.

The kind of grass growing from the shallow water varies; when very tall, as the blue grass mentioned as forming a guide to the spring, they are only found at its edges, and more frequently in places amongst it where there is open water. In the floating grass in the Upper river they are more readily found some distance from the edge. This grass is only about one foot high out of the water. In the fixed grass below Lake Pamalombi, and in the Lower Shiré, they are rare, except for about a yard from its edge. This grass is several feet high. The differences are most probably dependent on degrees of light and shade, either directly, as affecting the larvæ, or as affecting the growth of suitable foods.

Prophylaxis I deal with separately.

Breeding Grounds of Anopheles in British Central Africa.

(Supplementary Report.)

(Received January, 1900.)

Since I forwarded my Report on this subject, I have received copies of the 'British Medical Journal,' giving the results of similar investigations at Sierra Leone.

It is clear at the outset that we are dealing with different mosquitoes.

It may appear from my Report that little attention has been directed to "puddles." This was not the case. I was familiar with Ross's observations in India, and the first evidence I had of the existence of Anopheles in Africa was the presence of larvæ in a puddle on the way up the Zambesi. I failed to rear these larvæ.

In British Central Africa at first I mainly directed my attention to puddles, and it was only when I failed to find them there that I systematically looked elsewhere.

In the Upper Shiré district the soil is very sandy, and it is practically rainless for months; so puddles do not exist, unless the marshy tracts below or at the level of the river can be so called. In these, at any rate when the dry season is advanced, as I have already pointed out, the water is too peaty or stagnant for the larvæ to exist.

The suggestion has been made that the mosquito eggs may remain dormant for considerable periods. This is not the case here, as unless the eggs hatch within a few days they do not hatch at all.

No definite relationship between Anopheles breeding grounds and human habitations obtains here. The country is thickly populated, and native villages are always near permanent water, and consequently usually near Anopheles breeding grounds; but breeding grounds are also found at considerable distances from any dwelling.

Kerosene, as a laboratory experiment, readily kills the larvæ, but its application to the actual breeding grounds here is impracticable, as the water supply of the people would be affected.

The alterations produced by the wet season, so far, are as anticipated. The swamps surrounding springs are larger, and so the breeding grounds more extensive. They are also more numerous, as springs previously dry are now running. In some of these the larvæ were found early in the dry season, but not at the end of it. They are now again found, but only young forms.

The streams are fuller, and running stronger, and larvæ are now no longer found in them.

Development of "Crescents" in the "Small Dark" Anopheles prevalent in British Central Africa.

By C. W. Daniels, M.B. Received March 5, 1900.

The following observations were made on mosquitoes fed on an adult male European who had had "fever" off and on for a month. The first blood examination was made on November 23, and crescents only were then found. At that time and on the following morning he had fever, which left him in the evening. Crescents continued to be present in fair numbers, usually five or six in a fresh blood slide, and on November 26 I took him to Matope, on the Upper Shiré River, as there the Anopheles* I wished to experiment with are usually plentiful.

He remained at Matope for eight days. The mosquitoes (Anopheles) were far less abundant than at any of my previous visits, and a considerable number were required for control experiments, so I was only able to feed sixty-eight on the patient.

Of these sixty-eight, five died at various periods after feeding, but were too dry and brittle for dissection. Six died within thirty-six hours of feeding; these did not have any zygotes. The remaining fifty-seven died from two to nineteen days after feeding on the patient, and were examined—twenty-seven, or 47·5 per cent., had zygotes.

* Identified by Mr. F. V. Theobald as *Anopheles funestus*.

The temperature varied from 70°—84° F.

This percentage is in excess of the true proportion of infections resulting from a single feeding, as most of the mosquitoes were fed on the patient more than once.

Nineteen had been fed once only—five, or 26 per cent., had zygotes.

Thirteen had been fed twice—six, or 46 per cent., had zygotes.

Sixteen had been fed three times—ten, or 62 per cent., had zygotes.

Nine had been fed four times—six, or 66·6 per cent., had zygotes.

In all, the fifty-seven mosquitoes had fed 129 times, and in many of the mosquitoes the zygotes were of different sizes and stages of development, corresponding to different feedings.

In the five fed once, the zygotes were all of the same age.

In the six fed twice, the zygotes were of one age in three, and of two ages in three.

In the ten fed three times, the zygotes were of one age in five, of two ages in two, and of three ages in three.

Of the six fed four times, they were of one age in two, of two ages in one, of three ages in two, and of four ages in one only.

So that 129 feedings resulted in forty-six infections, or 35·5 per cent. This is quite as large a proportion as I think could be expected from a moderately good "crescent case," considering the very small capacity of this mosquito's stomach.

The zygotes in general appearance and course of development resemble those of Proteosoma.

The earliest forms, those found towards the end of the second day after feeding, were 7 to 9 μ in diameter. They were oval, had no defined capsule, and only stained faintly with basic stains. The pigment, relatively abundant in some, retained a close resemblance to that of the crescent. In some, even at this age, there was evidence of division of the protoplasm.

The zygotes steadily increase in size, and by the fourth day measure 20—25 μ. A capsule was now distinct, basic stains were taken readily, and the pigment had no characteristic arrangement. They obviously project from the outer wall of the stomach.

Beyond increase in size there was little change on the sixth day, by which time they measure 30—35 μ. Some were slightly granular.

On the eighth day the granular appearance was marked and general. Pigment had diminished, and they measured 40 μ and more.

The capsule can readily be ruptured, but the contents when expressed were only a granular mass.

On the tenth and twelfth days the cysts have reached their maximum size, 50—55 μ, as measured uncompressed and without a cover-glass.

When the capsule was ruptured, the contents of the cyst were poured out into the surrounding fluid. They partly consisted of free filaments, zygotoblasts (Ross's germinal threads), but mainly of clear

spherical bodies with irregularly radiating masses of filaments attached by one extremity.

The arrangement of filaments attached to central body seemed to me conjectural in Proteosoma, but was clear in these cases. Zygotes were traced up to this stage in eight mosquitoes.

Only two were traced further. Both of these had been fed more than once, so the ages are uncertain, 12—16 days in one fed three times, and 14—19 days in the other, also fed three times. In both, a ruptured and other unruptured cysts were found in the stomach, zygotoblasts were present in the body fluids, and in a few cells only in the salivary glands.

No bodies resembling the "brown spores" were present, but the observations were too few for this negative evidence to be of value.

The mosquitoes used were not reared from eggs or larvæ, and may have fed on other animals before feeding on the patient.

Though I should have much preferred to have used such mosquitoes, I do not consider that the results are at all invalidated, for the following reasons :—

Quite young forms, 7—9 μ in diameter, were found in several many days in captivity, in one case ten days, but two days after it had last fed on the patient, and in others after eight, six, and four days' captivity. Mixed infections were found only after repeated feedings on the patient. In those fed otherwise (on self) the infections were single.

The frequency of infection varied with the frequency of feeding on the patient.

Control experiments all gave negative results. These were as follows :—Twenty-two mosquitoes before the arrival of the patient. During his stay, thirty-eight from the room on his right occupied by myself; and twenty-four from the room on his left.

Thirty-nine others were fed on myself only, and examined four to eight days after the first feeding.

When the patient left, the mosquitoes were smoked out of the room, but on the second day sixteen were found in it and examined.

This gives a total of 139 mosquitoes, and zygotes were found in none, as against fifty-seven with twenty-seven positive results when fed on the patient.

To this I may add a large series of examinations of these mosquitoes in the past few months with negative results in all but one instance. In that already recorded a zygote was found in one out of four mosquitoes fed on a poorer crescent case than this.

The other known pigmented parasites in the district are Proteosoma, which is rare, and can be excluded, as its life-history is well known, and zygotes of such early development are not found so long after

feeding. Halteridium is common, but it is not carried by this mosquito —at least my experiments with it have failed.

Of unknown parasites we can, I think, safely infer that in any in which the later stages are so similar to those of known parasites, the early ones will also be similar.

Other mosquitoes :—

Of a large grey Culex, found in the Highlands and Upper Shiré, fifteen were fed on the patient, in some cases several times. No zygotes were found. The blood capacity of this mosquito is considerable, so these negative results are of value.

Three specimens of a brilliantly speckled, black and white Culex also yielded negative results, and early in the year I fed several of the large yellow, filaria-carrying Culex of the Lower Shiré, and two species of Anopheles, on a richer crescent case than this, in all with negative results, but the numbers of mosquitoes used were too small for the results to be conclusive.

"Notes on 'Blackwater Fever' in British Central Africa." By C. W. Daniels, M.B.

(Received November, 1900.)

The following notes refer only to cases in the above district. I have included in them cases observed by others as well as those seen myself, and am particularly indebted for much information to the medical officers, both of the Administration and the various missions, as well as for much assistance from others.

Occurrence.—The disease affects Europeans and Indians. During the year, June 1899 to June 1900, there were 33 cases, 31 in persons of European descent and 2 Indians.

The *European* population in 1898 was given as 338. It is probably still under 400, so that some 8 per cent. of the European population had this disease in the year.

The *Indian* population, Sikhs and others, is about 200, so that the proportion attacked was 1 per cent. This is probably above the true figures, as with a nearly stationary Indian population there have only been 6 cases in the past 5 years amongst them.

*Natives** (Negroes).—Opinions are divided as to the occurrence of the disease in this class. None of the medical men have seen a case. None of the adults in the armed forces (including carriers: these average upwards of 1000); none of the adults attached to missions, nor of the children attending mission schools, have been attacked. These would average some thousands.

It has not been seen amongst the numerous infants and children

* *Vide* Note 1 (p. 62).

brought to the missions for medical advice. Inquiries were made from 214 native mothers who have lost amongst them 313 children. They deny the existence of such a disease amongst the children, or of any of the deaths being due to it.

It can therefore, I consider, be concluded that this disease is at least of great rarity amongst the native negroes, and is much commoner in Europeans than in Indians.

Sex.—Both males and females are liable to the disease. Of 136 persons known to have had blackwater fever, 9 were females, or 1 in 15. At present the men (Europeans) seem, from returns received, only to be eight times as numerous as the women.

From this it might appear that the men are the more susceptible, but the figures are not conclusive, as the cases are collected from records of many years, and the proportion of females has increased of late. The greater number of women also are resident in the Highlands, and travel less than the men.

There is nothing to show that, under similar conditions, women are less susceptible to the disease than men.

Age.—The number of European children resident is small. Of those born the majority either die, are invalided, or early removed for prudential reasons. The only child attacked was a half-caste (European and native), aged about 5. The ages of the persons attacked vary from 19 to 38, the common age-limits of the residents.

Length of Residence.—This has a decided influence. Few cases occur during the first 6 months' residence. During the second half-year the number rapidly increases. They are most numerous during the second and third year, and become rare after 5 years' residence.

I can find no recorded first attack in any person resident more than 10 years. The number resident over that period is small.

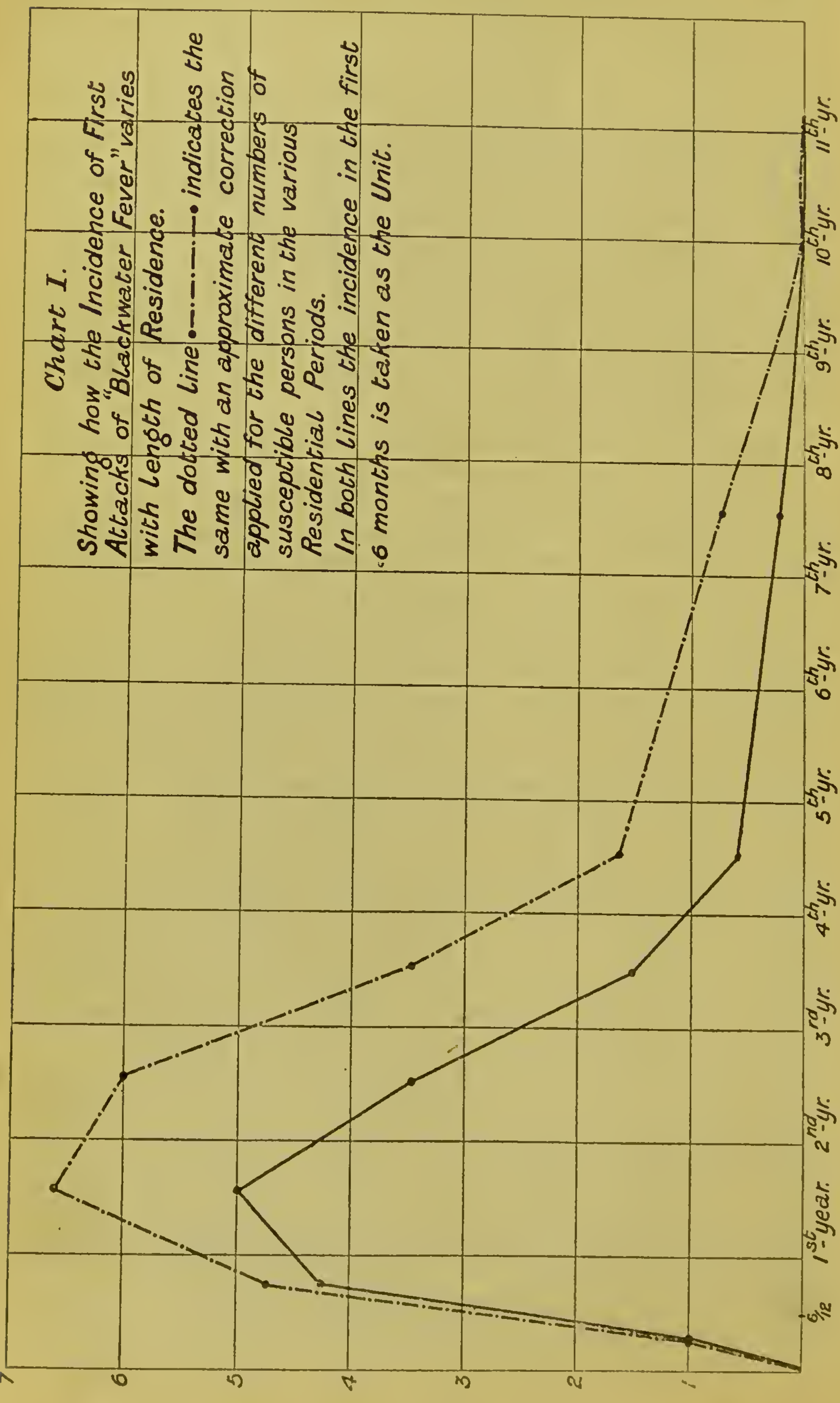
The attached chart (No. 1) shows the variation for the period of residence. The incidence in the first half-year is taken as 1.

Out of 114 first attacks, where the information on this point is sufficiently definite, 4 were in the first 6 months, 17 in the second half-year, whilst for the 2nd, 3rd, 4th, and 5th years the numbers were 40, 27, 12, and 5 respectively. There were 9 cases from the 6th to the 10th year, and none after that length of residence.

A correction is required, as the number of persons in any residential period steadily diminishes. Many leave after the first term of service and do not return. This term of service varies from 2 to 5 years. Others are invalided, and some die or leave for other reasons earlier. Taking the figures obtained from the returns received from 242 residents as representing the numbers of persons of the different residential periods, we have an approximation to the true correction.

The effect of this correction is indicated by the red line in the Chart (1). It does not materially affect the character of the curve.

According to both the corrected and uncorrected figures the liability to the disease is less after 5 years' residence than in the first 6 months.



Districts.—The greater number of the recorded cases have occurred in the Highlands at or about 3000 feet above the sea-level. For this there are two reasons. *First.* The number of residents in these Highlands is much greater than in the other districts. The correction for this alone reverses the figures. *Secondly.* Many of these cases were residents of other districts, visiting the Highlands for a change on account of ill-health, or for other reasons. Others were passing through the Highlands on their way home, sometimes when invalided home. Even of the Highland residents some of the attacks followed a short time after a visit to the lower lands.

On the other hand a few of the cases were in persons from the Highlands, attacked during a visit to other places. A true correction that would attribute each case to the district in which the disease was acquired is impossible. We know on the one hand that it may occur less than three months after arrival in Africa and also that attacks, and even first attacks, may develop months after leaving the country. The latent period may be long or short, and is variable.

Taking an arbitrary period of a fortnight as representing a not improbable latent period in a fair proportion of the cases, we should then find that the place of residence a fortnight or more previous to the attack would give a very different district-distribution of "blackwater fever" to that given by considering the place of onset.

In 97 cases (all 1st attacks) I have sufficient information on these points. The attack of "blackwater fever" commenced in 45 of these cases in the Highlands, in 40 at the Lake Level (Lake Nyassa and Upper Shiré River), and in 12 on the Lower Shiré River.

The susceptible (European) population is, in round numbers, 250 in the Highlands, 70 at the Lake Level, and 50 on the Lower Shiré River. I believe that this substantially represents the relative population of these districts for some years past.

It follows that if allowance be made for the number of susceptible persons in each district a very different district-incidence will be obtained.

Thus on the Lower Shiré, for each 10 persons residing there, 2·4 cases are on record; at the "Lake Level" for each 10 there have been 5·7; and in the Highlands for each 10, only 1·8 cases are recorded.

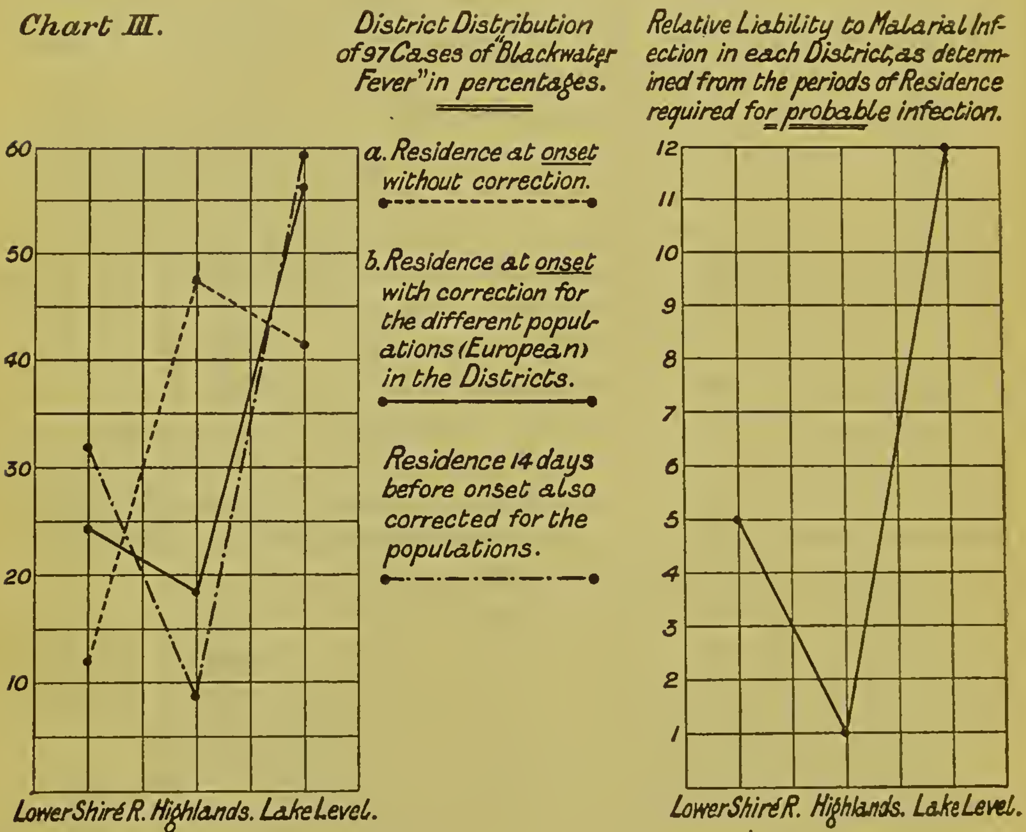
If we take the incidence in the Highlands as 1, that at the "Lake Level" will be 3·16, and on the Lower Shiré 1·33.

Some of these cases occurred immediately after arrival in a district, and should probably be credited to the district they had left. If we take the place of residence 14 days before the onset of blackwater fever instead of the place where the attack occurred, we find that of these 97 cases, 26 were resident in the Highlands, 51 at the Lake Level, and 20 on the Lower Shiré River 14 days before the attack commenced.

Corrected as before for the proportional numbers of susceptible

persons in each district, we find that for each population of 10 there were 1·04 cases recorded in persons from the Highlands, 7·28 from places at the Lake Level, and 4·9 from the Lower Shire River.

Again, taking the Highlands as 1, the proportion from the Lake Level is 7, and from the Lower Shire is 3·8. Chart III indicates these relations.



Whether these corrections, particularly the second, are too great or too small I am not in a position to state. A correction is essential and I introduce these figures, admittedly inaccurate, because conclusions as to the prevalence of the disease in different districts have been drawn on the mere totals without considering the obvious fallacies. Such conclusions are misleading and not warranted by the facts.

The correction is right in principle, and in the right direction. I believe that it does not go far enough. Such cases as one in which a person free from fever left one Highland district, spent some three weeks at the Lake Level, where he had "fever," and then after three months in another Highland district, got "blackwater fever," should be assigned to the Lake Level districts, as the patient had frequent recurrent attacks of fever during the three months he was in the second Highland district before the attack of "blackwater fever." In my present table this case is credited to the Highlands.

Change of District.—It is a common belief among the older residents

that a change of district, particularly from one level to another, causes "blackwater fever." Many cases have certainly occurred after such a change. The onset varies from a few hours to many days, or even weeks, after the change.

Cases occur in which there has been no change of district for months. Some of the cases are explicable on the ground that a belt of country where the incidence of blackwater fever is high has been traversed. In these cases some days may have been spent on the journey.

In British Central Africa changes of districts are frequent, and it is only a day's journey from the Highlands to a district a few hundred feet above the sea-level, or to one 1500 feet above the sea.

Exposure.—The attacks in a certain number of cases followed unusual exposure. In many cases there was no such antecedent.

"*Blackwater Fever*" *Houses.*—Two houses in particular have this reputation, as there have been several cases of "blackwater fever" in them. On inquiry, however, it is found that some of the cases were brought there with blackwater. The cases have occurred at long intervals, and it is doubtful in both houses if a single case was really contracted there.

Infection.—The disease is not considered to be in any way infectious. Wherever Europeans have settled, cases have occurred, but in no case do they appear to have been even remotely connected with previous cases. In such small groups as have occurred amongst parties of persons, the disease has in some of the instances broken out after the separation, and if dependent on a common cause that common cause was not a previous blackwater fever case.

Certain families seem more susceptible to the disease than others. Thus of one family of three brothers, two had it and died with hyperpyrexia. The third it is stated died with hyperpyrexia without blackwater.

Two other pairs of brothers had blackwater fever. In none of these cases was there any correspondence in the time of the attacks.

Venereal diseases and particularly *syphilis*, are by some supposed to be predisposing causes. Others consider excessive venery as a cause. Instances in support of this can be given, but in a considerable number of cases, including missionaries, such antecedents can be excluded.

Alcoholism can be excluded with even greater certainty. A large proportion of the cases occur in total abstainers. Some of these, as the members, male and female, of the missions, are above suspicion, and in a country where frequent transhipments of goods are required, and where all packages are carried for stages by carriers, any large supplies of alcohol to any of the scattered stations would attract notice and be commented on. Cases do also occur amongst persons known to be intemperate. I have not been able to satisfy myself that these are on the whole either more severe or more fatal.

Drugs.—Much importance has been attached to quinine as a possible cause of blackwater fever. More recently other drugs also, such as phenacetin, have been suspected.

In British Central Africa few persons are without a private stock of drugs. These are frequently abused. With very few exceptions obvious "fever" precedes blackwater, and consequently either quinine, phenacetin, or some other drug is taken. I only know of one case in which no drug had been taken; that was a fairly severe one.

As regards Quinine.—Cases occur in which no quinine has been taken for over a week, and sometimes not for a month before the attack. These cases, as indicated in the attached Chart II, show the same variety in the duration of the hæmoglobinuria, as those in which quinine had been taken.

An exception to this statement might be made as regards my collection of cases, in that amongst those in which quinine had not been taken there are no relapses, and none of the intermittent variety. F. Plehn, however, gives the intermittent form as the common one in non-quinine cases.

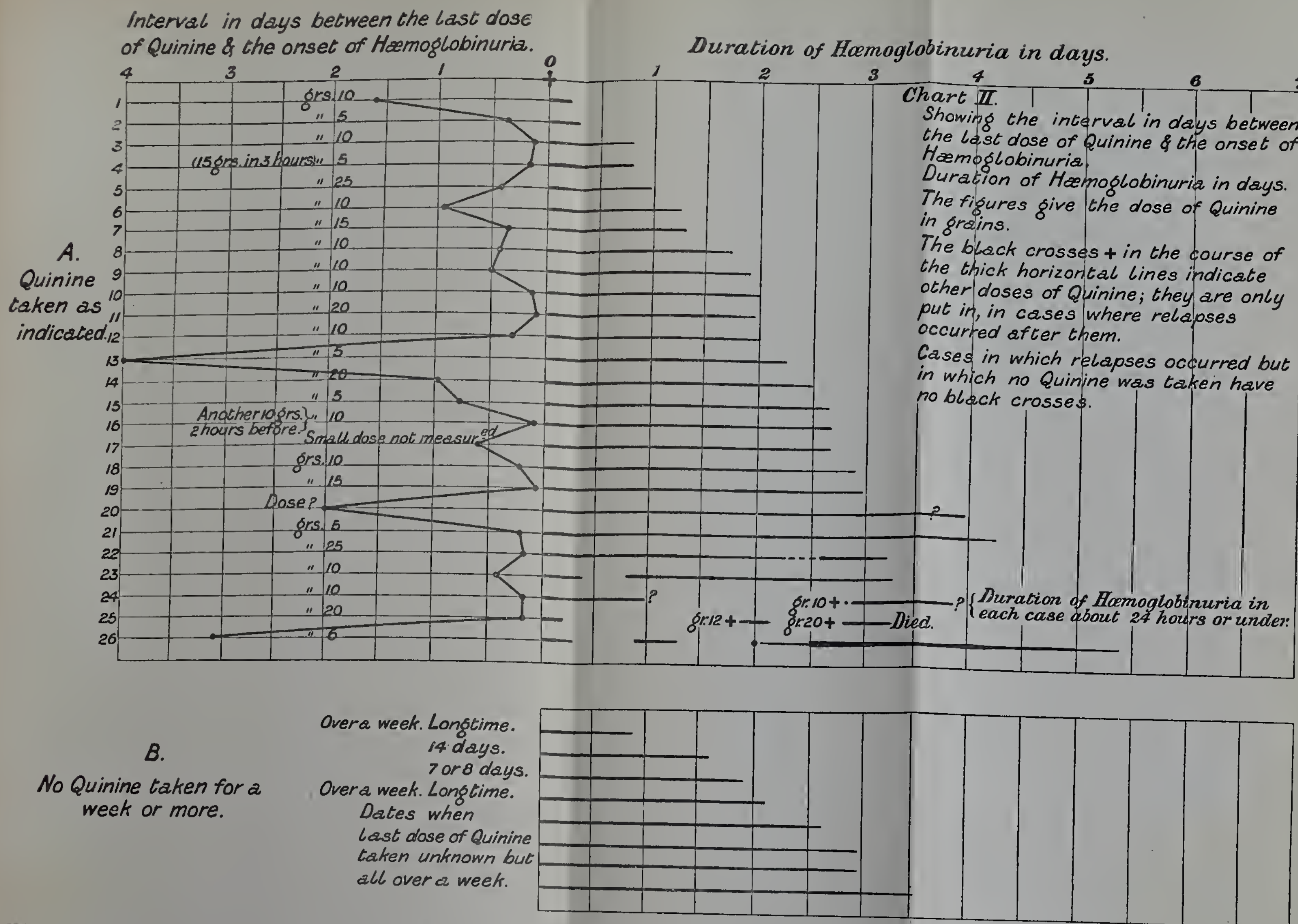
In the cases following the administration of quinine it will be noted that the interval between the last dose of quinine and the onset of the disease is very variable, four days down to one or two hours, and that there is no relation between the amount of the dose and this interval or the duration of the attack.

In several of these cases larger doses were taken both before and after the attack without any hæmoglobinuria following. In cases treated with quinine, sometimes in heroic doses, the hæmoglobinuria ceases, as it does in cases untreated.

These observations show that blackwater fever occurs independently of quinine. In cases where quinine has been taken, to attribute to it a causative action, it must be assumed that this action is independent of the dose, and that the resulting effect is variable, both as to amount and time.

In a few cases there is stronger ground for the belief that quinine is an important factor in the production of the disease. In some a larger dose of quinine has been taken than usual, but, on the other hand, other cases have followed a smaller dose than usual.

In a few cases not only has quinine been taken before the primary attack, but it has also been taken shortly before each relapse, and at no other time. Thus, in (No. 25, Chart II A) quinine, 20 grains, was taken three hours before the attack. The urine cleared in five hours. The next afternoon the patient, contrary to medical advice, again took 12 grains of quinine; hæmoglobinuria again came on in four hours and lasted four hours. The next afternoon, again in opposition to his medical adviser, he took another dose (20 grains) of quinine; hæmoglobinuria for a third time came on in two and a-half hours, and from this



N.B.—In a few of the other cases it is stated either that they were "not quinine takers" or "no quinine." In the great majority quinine had been taken, and in the majority very shortly before the attacks. These cases are excluded either because the information is insufficient or not quite reliable.

(2.) The *exact* time at which the last dose of quinine was taken and the *exact* time of the onset of hæmoglobinuria, even in the above cases, is uncertain; but for our purposes an error of two or three hours is unimportant.

attack he did not recover. For these particulars I am indebted to Dr. McCarthy Morrough.

Such cases undoubtedly make a strong impression on the observer, but are not conclusive. Similar relapses occur in cases not treated with quinine. In one case (Chart II A, No. 26, and Chart XV) 6 grains of quinine were taken three to four days before the onset of the disease. The urine cleared completely twice, and nearly so a third time. In two other cases there was an intermission (Charts IV and XIV).

The rule in British Central Africa is to take quinine only when the temperature is down in "fever" cases. If this rule had been followed in these three cases quinine would have been taken shortly before each relapse and at no other time. (*Vide* Temperature Charts. The time when quinine would probably have been taken is marked *.)

If quinine had been taken, these cases would have seemed to prove the dependence of the relapses on quinine. In none of the three cases was any quinine taken after the onset.

With so variable a disease as "blackwater fever," statistics are useless, so no comparison can be made between cases treated with quinine and those not so treated. It is not difficult, however, to select cases very similar and running similar courses with and without quinine, and to show that a continuance of the quinine, even in large doses, has no material effect.

For the notes from which these cases are selected I am indebted to Drs. MacVicar, Hearsay, Gray, Cross, Hardy, and others.

Malaria.—The relation of the disease to malaria is certainly not a simple one.

I have made frequent examinations of fresh blood specimens and films in ten cases, and of films only in six more. These films, two or three a day, were sent to me by Drs. Hearsay and Gray in cases I could not attend.

In one only did I find malarial parasites during the period of hæmoglobinuria, and that was about one and a-half hours after the onset, and even in that case no parasites were found at any subsequent examination.

In none of the other cases did I find either malarial or other parasites either during the period of hæmoglobinuria or in the subsequent pyrexial period.

In three cases I had the opportunity of examining the blood before the onset of the disease during the prodromal pyrexia, and in each case "ring" parasites were found. In these cases the parasites had disappeared in the hæmoglobinuria period. In five of the other cases pigmented leucocytes were found, and in two (fatal cases), though no parasites or pigmented leucocytes were found, still at the post-mortem examination the finely-divided pigment characteristic of recent malaria was present in the organs.

These observations show that malarial invasion of a recent date is a common antecedent of "blackwater fever," and that the parasites disappear during the attack. The evidence is against "blackwater fever" being in any way due to an exceptionally numerous invasion.

The suggestion has been made that the parasites are in an internal organ, particularly the brain. The absence of cerebral symptoms in blackwater lends little favour to this hypothesis, and the continued absence of the parasites during several entire cycles from the peripheral blood is, to say the least, unusual. The absence of any marked effect from the use of quinine is also opposed to this view, or to any view which necessitates as an essential a continued malarial invasion.

In three cases I examined the blood during the intermissions (four). In only one of these did I find parasites in small numbers.

These results corroborate in the main F. Plehn's observations in German East Africa. He attributes the disappearance of the parasites to the destruction of them by the altered blood serum. As, however, he and others have observed parasites in some cases during the course of blackwater fever, this explanation is hardly tenable.

If the disappearance or destruction of the parasites, or of some generations of them, is an essential feature of the disease, this destruction may be the cause rather than the effect of the hæmolysis.

In the great majority of cases, blackwater is preceded for one day or more by "fever," indistinguishable clinically from ordinary attacks of malarial fever. As regards its parasitology, this prodromal fever was also indistinguishable in the three cases mentioned above.

To this rule I know of two exceptions. The first is doubtful, as the patient had been feeling "out of sorts" for some time, and in consequence had been taking quinine. He was however able to travel in the usual way by machilla (a hammock) 40 miles, dine in public, and spend the night with friends, who noticed nothing amiss. During the night blackwater fever supervened. It terminated fatally, and the post-morten examination gave pigmentary evidence of recent malaria.

In the second case the onset was very sudden. The patient was, to the best of his knowledge, in good health, and was shooting at a target from his verandah when some abdominal discomfort caused him to go to the latrine, where he found that he was passing blackwater. The case was a fairly severe three days' attack, ending in recovery. There was no medical attendance, and the blood was not examined.

I am not prepared, on the clinical evidence only, of this case to consider it as a conclusive proof of a non-malarial origin. The chief etiological ground for considering "blackwater fever" to be a disease *sui generis*, and unconnected with malarial fever, is the want of correspondence between the seasonal incidence of the two diseases.

In British Central Africa there is no very marked seasonal incidence in either disease, and such as it is, it differs in different districts.

A difference in the seasonal incidence of the two diseases is of little importance, as whatever view may be taken, "blackwater fever" rarely follows a first infection. It usually occurs after several attacks or recrudescences of malaria, and at a variable period sometimes, as in cases occurring in England months after possible infection. This in itself would lead to a seasonal incidence different from that of malarial infections.

The etiological grounds in favour of a malarial origin of blackwater fever are:—

(1) Its prevalence in certain malarial districts. The prevalence in British Central Africa varies with the "prevalence of malaria" in the district, when a correction is made for the varying number of susceptible persons. With further corrections there is a closer correspondence (*vide* Chart III).

(2) Liability to recurrence after considerable intervals, or, though rarely, first attacks of both diseases when the patient is far removed from possible sources of infection. (Note 2, p. 62.)

(3) Diminished susceptibility to both diseases after prolonged residence in an infective district.

With Europeans the common history is much "fever" in the first three or four years; after that, little fever.

With the natives "fever" is common in childhood, and in adult life very rare. A considerable number of these "fevers" have been shown by their parasitology to be malarial.

Enlarged spleens give evidence of malaria usually more or less chronic. The exact relation is unknown.

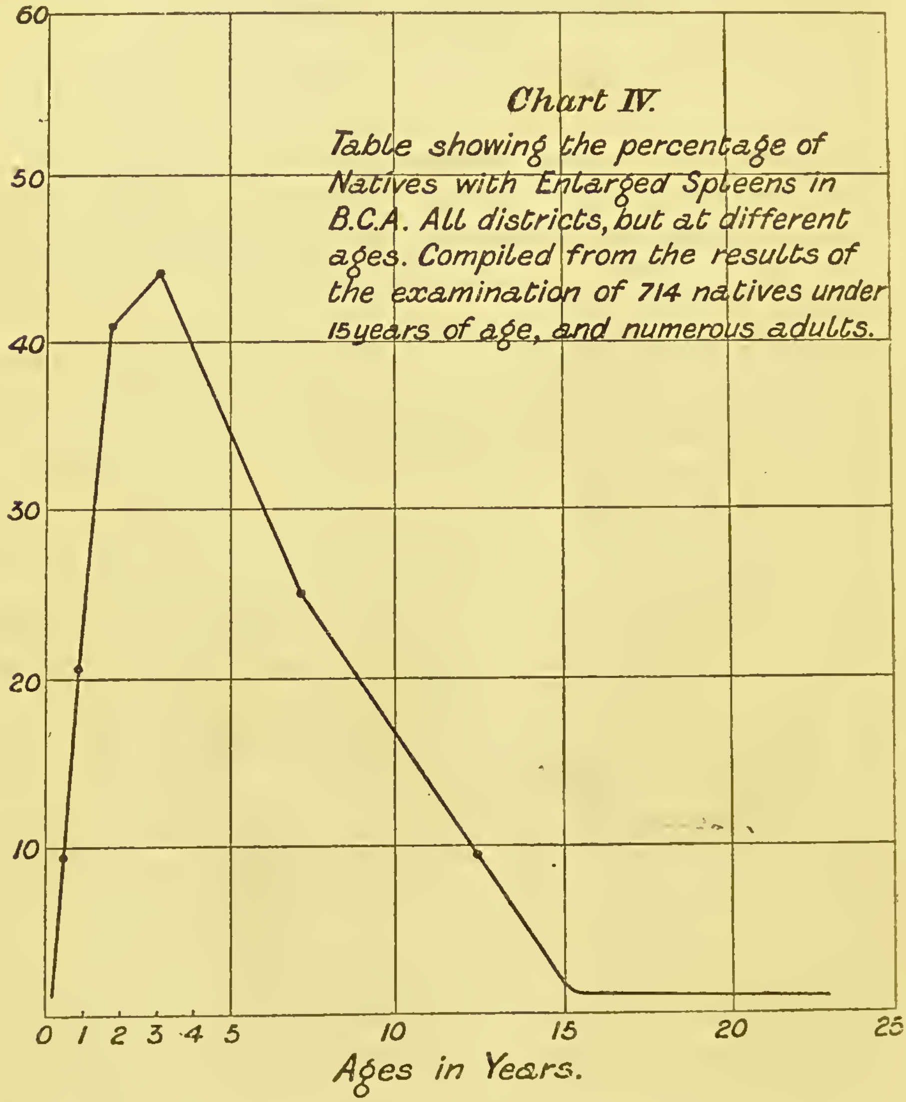
The age-incidence of this condition in the natives shows a rapid rise and gradual fall, similar to the residential-incidence of "blackwater fever" in Europeans (Chart IV).

The older cases of enlarged spleens, 10—15 years of age, are in the Highland children (10 out of 14), and the majority of those under one year (20 out of 24) at or below the 1,500 feet level. Similarly, the early cases of blackwater fever, those under one year's residence, are mainly (14 out of 21) in persons resident at or below the 1,500 feet level, and the majority (10 out of 14) of those after four years' residence are in persons mainly resident in the Highlands.

(4) If "blackwater fever" is a disease *sui generis* and not of malarial origin, it must also be either a disease originating *de novo*, or originating from some other unknown disease without the characteristic symptoms of hæmolysis and hæmoglobinuria.

Nature of the Disease.—"Blackwater fever" is essentially an acute hæmolysis of sudden onset, short duration, and spontaneous cessation. One of the products of the blood destruction is discharged in quantities with the urine as free hæmoglobin, or more rarely, as methæmoglobin.

It is accompanied by pyrexia, not definitely of malarial or other type. It is usually preceded by pyrexia, and is often followed by a more or less prolonged pyrexia, which may be continued, remittent, or irregular. In occasional cases hyperpyrexia occurs.



The blood destruction is great. In cases where the hæmoglobinuria lasts for over two and a-half days, the number of red corpuscles fell to 1,038,000, 1,290,000, 1,366,000, and 1,680,000 respectively, from presumably little below normal.

Even in shorter cases, lasting about twenty-four hours, there is fall to below 3,000,000. In some cases at least, the hæmoglobin is more reduced than the corpuscles.

The prodromal pyrexia has not been much studied, as cases rarely come under medical observation at this stage, and even when they do, they are not recognised as blackwater at this period. During this stage rigors are unusual, and not marked. In this they resemble

ordinary malarial attacks in British Central Africa. During the hæmoglobinuric period severe rigors are the rule; they are often initial, but may be later. Sometimes there are repeated rigors. Complete absence of rigor is rare, but does occur.

With the cessation of the hæmoglobinuria there is usually a fall in the temperature sometimes to subnormal. These changes and the subsequent pyrexia are illustrated by the Temperature Charts.

Shortly after the onset of the disease the conjunctivæ and skin show an icteric tinge closely resembling jaundice. In such cases as I have seen there has been no bile pigment in the urine. There can be little doubt that this colour is derived from the blood pigment. This coloration may be intense, especially in suppression cases.

The condition of the skin varies, but as a rule there is profuse diaphoresis even when the temperature is high. It is frequently intermittent.

The pulse-rate is not much raised considering the temperature, and in cases I have seen has been about 90, rarely up to 100. In other cases noted here it has sometimes been much higher.

As the anæmia advances the pulse usually becomes dicrotic. Respirations also become more frequent; 28—32, whilst keeping still, are not uncommon.

The severity of the disease varies greatly according, 1st, to its duration, and 2nd, as regards complications. The duration, when there are no relapses, varies from a few hours up to, as a common period, rather under three days. Some observers consider the last as the common type. Cases in which the hæmoglobinuria persists longer than three days are rare without either partial or complete intermissions.

There seems no reason to attempt to distinguish separate forms of blackwater fever. Intermediate forms occur as regards duration or any single symptom. Such divisions as "quinine form," "bilious" forms, &c., may be misleading and cause confusion.

Relapses are common. They may occur before the urine is quite free from hæmoglobin, in which case the hæmoglobinuric period may be much over three days. They commonly occur after the urine has been clear for a few hours, and more rarely after several days or even two or three weeks' intermission. There does not seem to be any definite relation between the primary attack and the relapses as regards duration. The first attack may be a short one, and the relapses long, or *vice versa*, or they may be each of about the same duration. (Charts II A, 22 and 23, and Temperature Charts IV, XIV, and XV illustrate this condition.)

Vomiting is a common symptom and is frequently severe and persistent. When excessive the prognosis is unfavourable. In rare cases there is either no or very little vomiting.

Hiccough is very common. It occurs in mild as well as in severe cases, and unless excessive is of no prognostic import.

Hæmorrhages are not a usual feature of the disease, but occur in some cases. The commonest form is epistaxis, but in two there was hæmatemesis and in one hæmorrhage from the bowel.

Glandular enlargement was noted in three of the collected cases, in each case in the neck. In one of these cases there was extensive suppuration, terminating fatally. In some cases of malaria there is glandular enlargement.

Gastro-enteritis with dysenteric symptoms appears to have occurred in several cases. This I have not seen.

The mortality of the disease is variously given. It is probably overstated as a rule. There is a tendency to report all deaths, when there has been no doctor in attendance, as "blackwater fever." On the other hand, cases that recover from what appears to have been "blackwater fever," in the absence of medical testimony, are doubted. The fatal cases are remembered whilst the recoveries are forgotten. For these reasons I consider that the figures given below exaggerate the gravity of the disease.

In all, I have collected some accounts of the disease in 136 persons from the district. Amongst them they had 184 attacks.

Of the 136 first attacks	31 or 22·7	per cent. were fatal.
,, 33 second attacks	8 or 24	,, ,,
,, 15 third or fourth attacks	2 or 13·3	,, ,,

In this variable disease the mortality is no guide to the success of the line of treatment adopted. In the cases of a few hours' duration deaths are rare; in those lasting over two days deaths are common. A collection including a large proportion of short attacks will give a low mortality; whilst a series in which few of these mild cases are included will give a high mortality.

In British Central Africa some of the medical men seem to have seen little of the milder forms till this year, but they have occurred for many years past.

The supposition that the milder forms are on the increase, like the statement that "blackwater fever" itself is of recent appearance, is not, I think, warranted by the facts known.

The increased European population, greater facilities for travel, and the larger number of medical practitioners have enabled a larger proportion of the cases to be seen, and that at an earlier stage. The attention directed to the disease has led to cases being recorded which otherwise would have been speedily forgotten.

There are three main causes of death—suppression of urine, cardiac, failure, and hyperpyrexia.

Of these, suppression is the commonest. This is rarely complete,

though the amounts passed may be very small, and at the rate of only a few drams daily.

I have not seen this complication. From notes supplied to me by Drs. Gray and Hearsay, we find that in one case 7 ounces of urine were passed in five days; in another, 8 ounces 1 dram were passed in five days; in another 2 drams in two days, and in another 25 ounces were passed in the first twenty-four hours of the disease, and only $10\frac{3}{4}$ in the whole of the remaining nine days.

It is noteworthy that, in spite of the small amounts of urine passed, not only does it become free from hæmoglobin, but even that it may be free from albumen. This shows that the products of the hæmolysis, failing a passage by the kidneys, are removed in some other way (Note 3).

In cases of blackwater fever terminating in recovery the amount of urine passed is variable. Whilst there is much hæmoglobin the amount passed is usually much above normal. As the urine clears it falls below normal and may remain below for days or only for a brief period. This variation takes place even in the milder cases. Urine Charts A (1), (2), (3), and (4) illustrate this condition.

Suppression usually occurs when the urine is commencing to clear, and this drop may be taken to indicate a tendency towards it. The hæmoglobinuric urine appears to act as a diuretic. There is evidence, however, that it acts as an irritant on the genito-urinary tract.

Micturition is frequent; sometimes urine is passed every hour or even more frequently. This is particularly so during the second day.

At this time much bladder epithelium is found in the urinary deposit. Dysuria and tenesmus are rare but occur. There is discomfort, rarely amounting to pain in micturition, and in two cases there was actual retention. Retraction of the testicles is common. These symptoms disappear as the urine clears.

It is tempting to attribute the suppression to mechanical causes. There is little evidence of any important structural change in the kidneys. With the disappearance of the hæmoglobinuria there is a great fall in the amount of albumen, and usually in a day or two and sometimes even after the first micturition none at all is found. Casts persist longer, and an occasional one may be found weeks after the attack.

The symptoms associated with this suppression are not those of uræmia. Consciousness is maintained till near the end; convulsions are very rare and even muscular twitchings are unusual. Vomiting is usually marked. The temperature is often subnormal. (Note 4.) Temperature Chart 12 is that of a suppression case reported by Dr. Gray, P.M.O., British Central Africa.

A temporary suppression could be accounted for, when it occurs early, by the irritation set up by the hæmoglobinuric urine; and the

late cases by the combination of the fall of the blood pressure, the anæmia and the cessation of the excretion of diuretic constituents of the urine (hæmoglobin), but neither of these sufficiently explain the persistence of the suppression.

They might explain the commencement but not the continuance.

The accumulation of pigment (yellow) and of ferruginous materials in the liver, as found post-mortem, indicate the alternative method of eliminating the hæmolytic products from the blood.

Cardiac failure is common. It has in several cases been the cause of death as a result of slight exertion.

Hyperpyrexia is not common, though pyrexia is often severe. In the cases of which I have notes, it occurred after the hæmoglobinuric period. It does not seem to be controlled by quinine or antipyretics (Temperature Charts 10 and 11).

Second attacks are common. Of the 136 patients, 33 are known to have had two or more attacks, 24 per cent. As many persons leave after one attack and do not return, this probably understates the liability. The longest interval between the first and second attack is nine years. It is often less than one year. Second attacks under a month would be considered as relapses.

The health between the two attacks is usually good.

F. Plehn states that the mortality is greatest in the first attacks. My returns are not sufficiently numerous to justify any decided conclusion, though the actual figures indicate a slight increase in the mortality in second attacks and a decreased one in subsequent attacks.

In some persons each attack resembles the first. Thus one person has had three attacks each lasting only a few hours, another had two attacks within a year, each lasting just under two days, and a third two attacks, each lasting two and a half days.

This is not an invariable rule, as one person whose first attack lasted under twenty-four hours had his second attack nine years after, which lasted a full three days.

This tendency to persistence in type of the disease in an individual perhaps accounts for the absence of a markedly increased mortality with later attacks.

A severe first attack is fatal, or the person permanently leaves the country. Second attacks will, in the majority of cases, be in persons who had slight or only moderately severe first attacks, and as far as the type remains the same will have slight or moderately severe second attacks.

Treatment.—The popular belief in an excessive mortality from "blackwater fever" has led in the past to somewhat heroic treatment. The rapid course of the disease, with the progressive failure in strength, has resulted in frequent changes in treatment before any one method has had a sufficient trial.

Errors as to the true nature of the disease have been common. By some it seems to have been considered as a hæmorrhage, and hæmostatics, such as ergot, perchloride of iron, &c., have been freely resorted to, not only by the mouth or hypodermic injections but also by intrarenal injections.

Restriction of fluids seems to have been advocated by some partly for this reason, but mainly with the idea of checking vomiting. Quinine has been very freely used by some, subcutaneously and otherwise.

Comparisons of the mortality under different treatments is useless on account of the varying severity of the disease.

Judging from individual cases I have seen under various methods of treatment, and comparing them with notes of other cases supplied to me, I do not think that any treatment hitherto employed has the slightest influence on the duration of the hæmoglobinuria or hæmolysis.

From the depth of colour of the urine passed in the early stages, the duration of the attack can be fairly correctly estimated, unless relapses occur, irrespective of treatment.

Parallel cases, with or without quinine or any other specified drug, can be easily found. Alteration or cessation of a treatment does not make any material difference.

Quinine has little or no effect on the temperature, and antipyretics, such as phenacetin, have so temporary an effect, sometimes followed by a greater rise, that I consider their use doubtful and their repeated use dangerous (*vide* Temperature Chart 4).

Whatever the connection with malaria may be, I think quinine should be avoided unless there is direct evidence of *present* malarial infection as shown by finding parasites. Even when parasites are present, I should be inclined to use it with caution, as it increases the vomiting, and in large doses causes much depression.

The treatment, therefore, is necessarily *symptomatic*. The chief danger is, or is heralded by, suppression, and consequently diuretics have been extensively used.

Terebene, introduced by Dr. Kerr Cross, has been extensively employed, and a considerable number of cases so treated have recovered. In the cases I saw, no effect seemed to follow its use or disuse. In cases of suppression, no rise in the amount of urine has followed its administration. Considering the signs of genito-urinary irritation present in the blackwater stage, a less irritant diuretic would appear to be indicated, but I cannot say that I have seen ill-effects follow its use. In some cases it is said to cause vomiting. Non-irritating diuretics have also been freely used, and recoveries have been numerous.

The simplest form is, perhaps, that of taking large amounts of fluid —plain water, soda water, lemonade, &c.

A treatment frequently practised in the past year was Sternberg's treatment for yellow fever; this was introduced by Dr. Hearsay. Frequent doses of bicarbonate of soda, with minute doses of perchloride of mercury, are given. In some eleven cases so treated there has been little vomiting and no suppression.

It is, in my opinion, worthy of a fuller trial, and is quite harmless. It has not yet been fully tested by a suppression case. It can only be considered as a symptomatic treatment.

In cases where the vomiting has been persistent, morphia has been used hypodermically.

Sulphonal checks the restlessness so common in the disease. No ill-effects have been observed.

Most practitioners make a strong point of "feeding up" the patients, particularly with various meat extracts; they are not necessary, and, considering the large amount of waste products to be excreted, may be injurious. One patient, who recovered from a severe attack, treated himself on lime juice and soda water in large quantities, but had no food at all, "not even milk." In a severe case, stimulants are required later on; too early a resort to them is to be deprecated.

Prophylaxis.—Till the origin of the disease be known it is useless to discuss the question. If the views I hold be correct, it would be bound up with the prophylaxis of malaria. Comparisons between "blackwater fever" and various other diseases have been made.

Yellow fever resembles it in that there is a similar racial susceptibility and immunity, in the variability of the severity and duration of the disease, in the unfavourable prognosis with excessive vomiting, and the fatal augury of suppression.

Apart from bacteriological grounds, blackwater fever is distinctly separated from yellow fever by not being contagious or occurring in an epidemic form.

Paroxysmal hæmoglobinuria has merely the resemblance that hæmoglobin is present in the urine in both. Any attempt to otherwise compare the two fails.

For etiological purposes it is unimportant, as paroxysmal hæmoglobinuria is a disease of great rarity, not markedly more common in the tropics than elsewhere, whilst "blackwater fever" affects a *considerable percentage* of the European population under varied climatic conditions in malarial districts of Africa alone. It occurs but only rarely in other malarial countries, India, British Guiana, West Indies, &c.

With anæmias, including malarial anæmia and cachexias, it has the differences of its short duration, rapid course, and uniform tendency to speedy recovery, unless complications terminating fatally arise.

If kala azar be taken as the type of the malarial cachexia, it would be a secondary fever due to, or accompanied by, chronic visceral changes persisting after the malarial invasions had subsided. Black-

water fever, if a malarial origin were admitted, would have to be considered as a secondary disease characterised by acute temporary hæmolysis, not associated with causative visceral changes, but originating with an abrupt subsidence of a malarial invasion.

With ordinary forms of malaria, including the comatose one, there are no analogies at all.

The nearest perhaps is the "algide" form. In exceptional cases of blackwater fever the onset has been with marked collapse and continued prostration, whilst the urine has not contained large amounts of hæmoglobin. Such a case might be considered as an intermediate form.

In the present state of our knowledge of the disease opinions are of little or no value. The weight of evidence is in favour of a malarial origin. The character and parasitology of the prodromal stage appears to me to be the important period, and is not likely to be worked out till blood examinations in cases of malaria become a routine.

In conclusion, I consider that the balance of evidence is in favour of the view that "blackwater fever" commences in individuals suffering at the time from an invasion by the malaria parasites; but that there is no evidence to show that the attack actually depends on an exceptionally large number of these parasites, an exceptional degree of anæmia or visceral alteration, or on climatic influences or the exhibition of drugs.

What actually determines an attack of "blackwater fever" I am not in a position to state. Before the problem can be solved much more information is required regarding the period immediately preceding the onset of the attack, especially in connection with the parasitology and condition of the blood at that period.

Such data are peculiarly difficult to ascertain, as there is no known means of diagnosing the disease in the prodromal period.

The whole question of malarial sequelæ, including secondary fevers and the causation of visceral changes, requires more investigation, as it has been comparatively neglected since the knowledge of malarial parasitology became general.

The mode of production of immunity, temporary and persistent, is as yet unknown, and also requires much more study.

"Blackwater fever" may be due to some derangement or interruption of such processes, and therefore in our present state of knowledge it is futile to theorise.

Certain manifestations of malaria appear to be more common in some malarial countries than in others, though the parasites appear to be indistinguishable.

It is possible that these differences may depend on the different definitive hosts of the malaria parasites.

Several species of Anopheles have been proved to carry the malaria parasites. Mr. F. V. Theobald has identified three of the Anopheles found in British Central Africa as three found on the West Coast of Africa; but one, *A. paludis* (Theobald), is in the form of a distinct variety. These mosquitoes have not been found in other countries.

If the prevalence of "blackwater fever" in Africa is due to one or all of these hosts, *Anopheles funestus* must be one of those implicated.

A knowledge of the exact geographical distributions of the various species of malaria-bearing Anopheles is required in this connection, as well as the geographical distribution of "blackwater fever" and of special manifestations of malaria.

NOTES.

1. The natives of British Central Africa have the woolly hair of the negro. The features are coarse but not typically negroid, and there are considerable tribal and individual variations in this respect. They are of various shades of colour from brown to black.

The tribes I have had most dealings with are the Yao, Manganja, and Angoni. There is a slight Arab admixture in some districts, and a larger Zulu in others. As a whole they belong to the Bantu division of the African races.

2. Two cases of "blackwater fever" have occurred in persons after arrival in England who had never had blackwater fever during their residence in British Central Africa. They had both had ordinary "fever" in Africa.

3. In early "suppression cases" the anæmia and icterus continue to increase although little or no hæmoglobinuric urine is excreted. The case (Chart 12) under the care of Dr. Gray is the only one I know of in which the number of corpuscles was estimated. Suppression set in within twenty-four hours of the onset of the disease. The number of corpuscles, as determined by Dr. Gray was 3,170,000 on the first day, 2,360,000 on the second, 2,180,000 on the third, and 1,740,000 on the fourth day. During the second, third, and fourth days a total of 4 ounces of urine was passed. The estimates for the next two days were 1,800,000 and 1,630,000 respectively. Suppression continued till death on the tenth day.

4. There appears to be considerable variation in the symptoms associated with suppression in "blackwater fever." In occasional cases, as in some of the suppression cases in yellow fever, the patient is perfectly rational and conscious just before death. The cerebral symptoms that occur are drowsiness, irritability, and sometimes mental weakness or confusion. Delirium during sleep is common. Convulsions are very rare. Coma only occurs, and not always even then, shortly before death. Life is usually prolonged for three or four days after the onset of suppression, but may be as long as nine days.

There is, as a rule, little disturbance of the special senses, though loss of vision has been complained of. The pupils are in some cases dilated. Deafness is common only in cases treated by quinine.

There is steady loss of muscular strength in most cases, but not in all. Muscular twitchings are usually absent, even to the last. As a rule there is much vomiting, and often hiccough.

Occasionally a "uræmic smell" has been noted, but this is not usual. Anasarca does not occur. The urine may be free from albumin towards the end.

ILLUSTRATIVE TEMPERATURE CHARTS (pp. 64–77).

Chart 1.—"Blackwater fever." Mild attack. Prodromal period taken for ordinary malarial attack, and parasites found.

Onset without rigor.

Post-hæmoglobinuric pyrexia.

The charts in three previous attacks of malaria and one subsequent attack attached.

,, 2.—"Blackwater fever." Severe attack. This followed repeated attacks of fever for a period of three months.

The day before the attack "fever" taken to be ordinary malaria. Parasites found in fair numbers.

No complications. Post-hæmoglobinuric pyrexia very slight.

,, 3.—"Blackwater fever." Severe attack.

Prolonged and severe post-hæmoglobinuric pyrexia not markedly affected by quinine in considerable doses.

,, 4.—"Blackwater fever." Severe attack.

Prolonged and severe post-hæmoglobinuric pyrexia.

Treatment mainly by phenacetin. Temporary effect of this drug followed in some instances by a higher rise.

In this case there was an intermission in the hæmoglobinuria, during this intermission parasites were found.

Quinine *not* given during the intermission; if it had been it would, according to custom, have been given when the temperature was down only (*), *i.e.*, in this case about five hours before the relapse.

5.—"Blackwater fever." More continuous form of post-hæmoglobinuric pyrexia.

,, 6.—"Blackwater fever." Mild attack.

No post-hæmoglobinuric pyrexia.

,, 7.—(Indian) "Blackwater fever." Patient was under treatment for enlarged spleen, anæmia, and chronic "fever," secondary malarial fever (?).

Unusually slight pyrexial disturbance, either before, during, or after the hæmoglubinuric period. I can find no record of a case similar in these respects.

8.—"Blackwater fever." Medium severity. Prodromal period not marked by definite illness, as patient was able to live an ordinary life. Temperature was taken night before the attack and found to be raised, 105° F.

Post-hæmoglobinuric pyrexia moderate. Very little treatment. Good effect of an occasional dose of phenacetin (?).

Chart 9.—"Blackwater fever." Two attacks in same person at an interval of four months. Good health in between.

Last attack came on about eight days after last dose of quinine.

Second attack came on about twelve hours after last dose of quinine.

Charts 10 & 11.—"Blackwater fever." Attacks not severe, but *hyperpyrexia* in post-hæmoglobinuric period.

Chart 12.—"Blackwater fever." Suppression of urine. Fatal.

Followed untreated malaria. No quinine taken for a fortnight.

Post-hæmoglobinuric pyrexia appears to be rare in suppression cases.

,, 13.—"Blackwater fever." Severe case followed by acute lobar pneumonia.

No definite marked prodromal period. Malaise only. Temperature not taken. Post-mortem showed pigment disposed as in recent malaria.

,, 14.—"Blackwater fever." Relapse occurring on the third day before the urine had quite cleared.

According to the usual local rule for the administration of quinine, it might have been taken on the morning of the second day, but more probably would not have been taken till the third day, in which case the relapse would have been attributed to the quinine. None was taken.

,, 15.—"Blackwater fever." Series of relapses. The early ones of short duration and methæmoglobin only in the urine. The final attack was hæmoglobinuric and came on before the urine was quite free from methæmoglobin. Hepatic pain a marked feature, both of the early attacks and also in the rises of temperature in the post-hæmoglobinuric period.

Quinine, according to usage, would have been taken on the second and third days (*), and the relapses then would have been attributed to it. None was taken.

Probably the patient's temperature was also down on the first day of the chart, as he was out.

In this case there was hardly any vomiting.

(a) DISEASE

Malarial Fever.

NOTES OF CASE

Chart I.

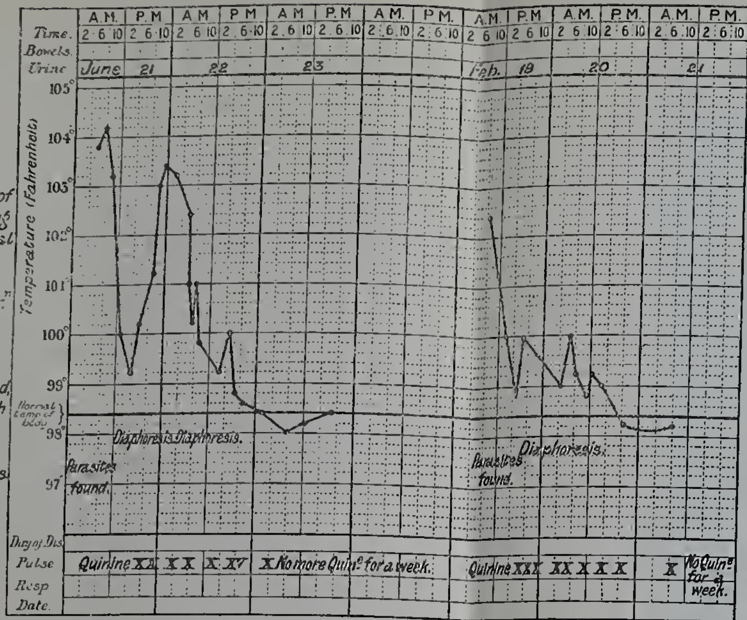
10th, 11th, & 12th, attacks of Malarial Fever, terminating in recovery without unusual symptoms.

13th attack & during its course "Blackwater Fever."

A subsequent Pyrexial Fever non-malarial.

14th attack of Malarial Fever, one cycle untreated, the second treated with Quinine.

No definite subsequent attacks in next 5 months.



(b) DISEASE

Malarial Fever.

NOTES OF CASE

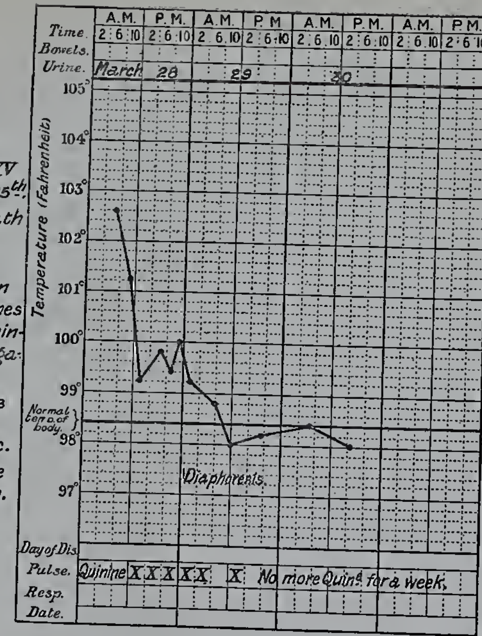
Travelling. Quinine grs. XV had been taken March 25th.

Had been in good heath since last attack of fever Feb. 19th.

Temperature had been taken two or three times a week & blood examinations made, with negative results.

Quinine X or XV grains every 5 days and an occasional other dose.

"Fever" came on in the night. No films taken.



(c) DISEASE

Blackwater Fever 1st attack.

Name D.

NOTES OF CASE

Frequent short attacks of fever in previous 11 months all treated energetically with Quinine.

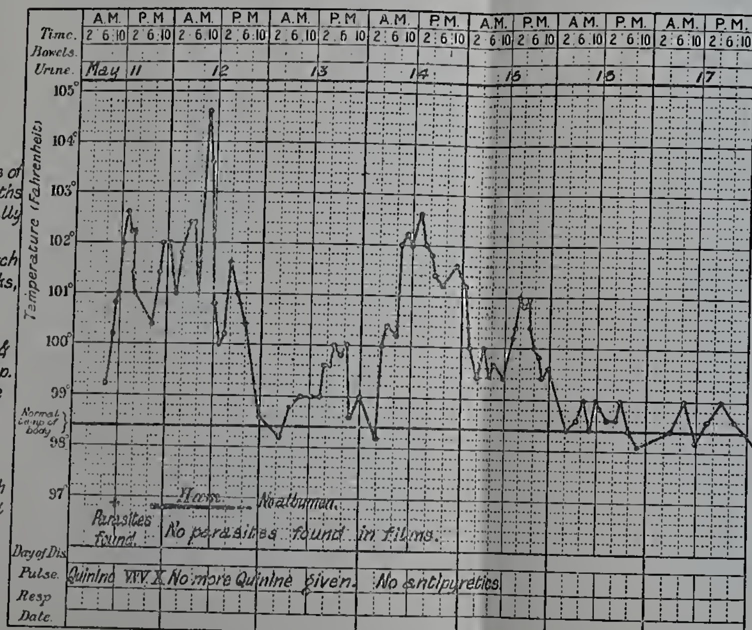
Last attack of "Fever" March 28th. An interval of 7 weeks, the longest since June.

Health in interval fair, considerable lassitude & want of appetite, but Temp. never found to be above normal.

Quinine gr. X. two days before onset of "Fever."

Onset of "Blackwater" with severe abdominal, not renal pain. Relieved by induced vomiting. No rigors.

RESULT Recovery.



(d) DISEASE

Malarial Fever, 16 days after "Blackwaer."

NOTES OF CASE

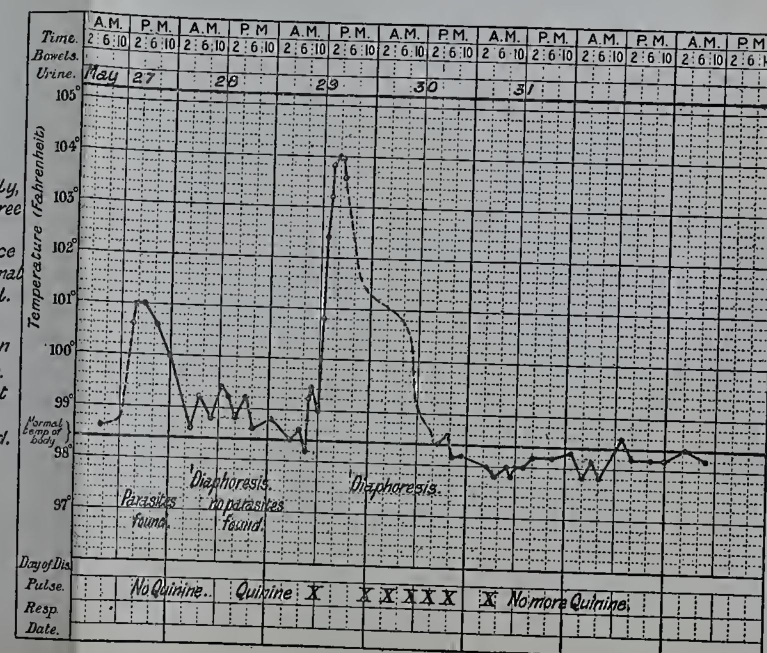
Temperature taken daily, & frequently two or three times a day since May 17th. Once or twice 99°F., but usually normal or slightly sub-normal.

No Quinine taken.

Last Blood Examination 2 days before. Negative.

Parasites found at onset of fever, none 2nd day.

Third day not examined.



DISEASE.

Blackwater Fever
1st attack.

Under care of Dr. Hearsay.
Name. W.
Age. 27.

NOTES OF CASE.

Chart 2.

First had fever three months ago, since then has had it about every other week.

Had 3 days fever 12 days before, and the 2 days before this attack.

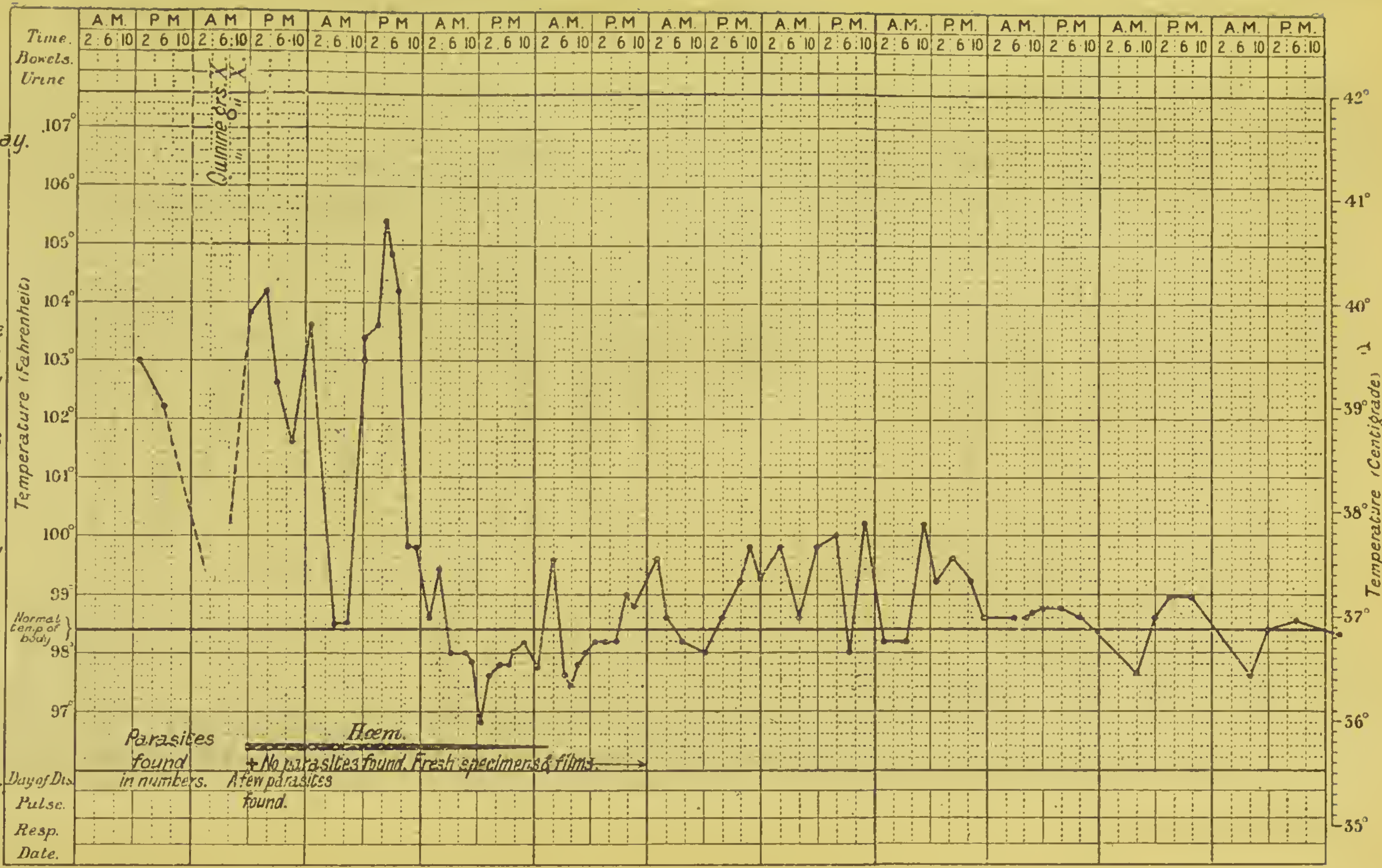
Has taken 250 grs. of quinine in the 3 months, but never as much as 20 grs. in a day.

Treatment after onset, Sodium Bicarbonate & Liq. Hydrarg. Perchlor.

Herpes Preputialis during convalescence.

Was free from "fever" for some weeks after the attack.

RESULT Recovery.



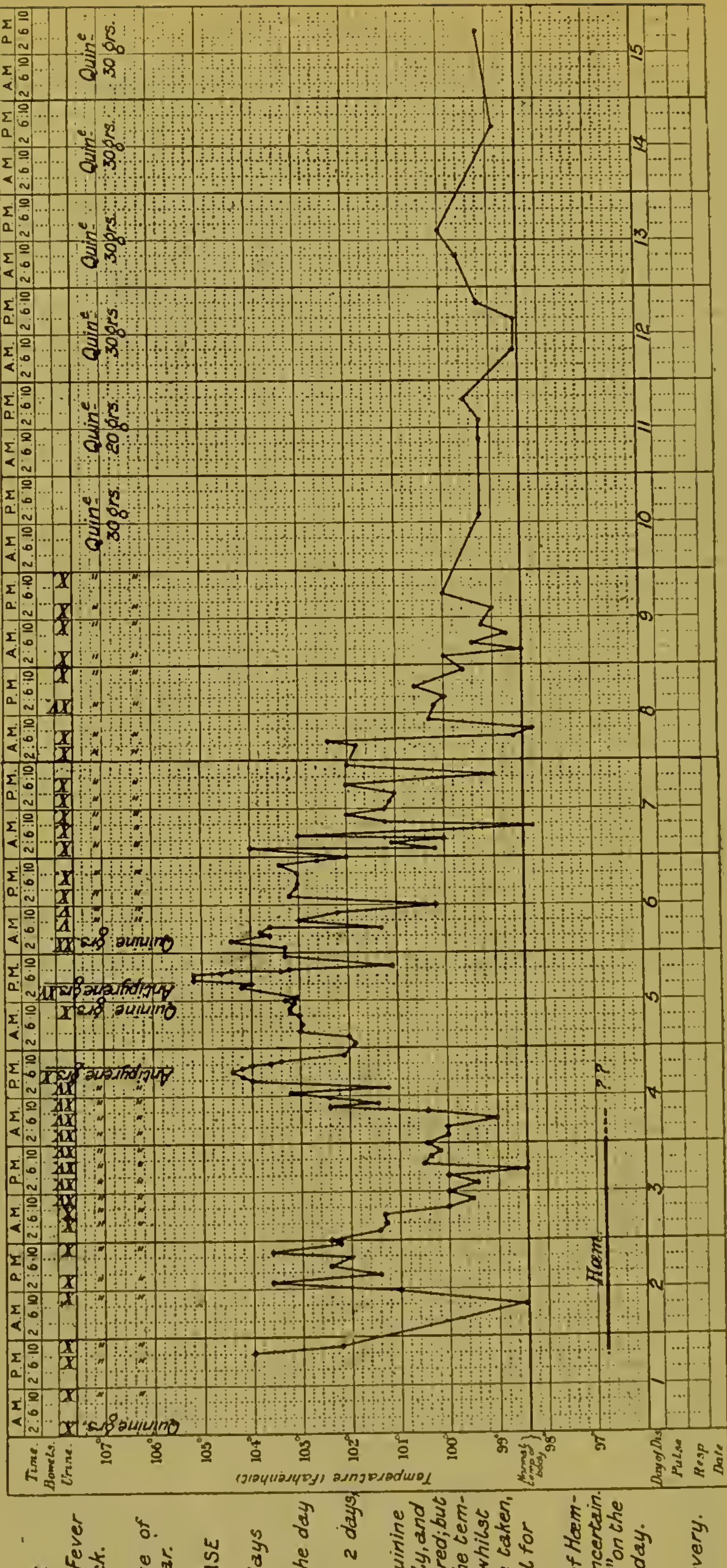


Chart 3.

DISEASE

Blackwater Fever 1st attack.

Name A.

Under the care of Dr. MacVicar.

NOTES OF CASE

"Fever" for 3 days previous.

Temperature the day before 105°F.

Had fever for 2 days, a week ago.

In this case quinine was given freely, and patient recovered; but not only did the temperature rise whilst full doses were taken, but did not fall for several days.

The duration of Hæmoglobinuria is uncertain. It was "clearing" on the morning of 4th day.

RESULT Recovery.

Chart 4.

DISEASE

Blackwater Fever
2^{nd} attack.

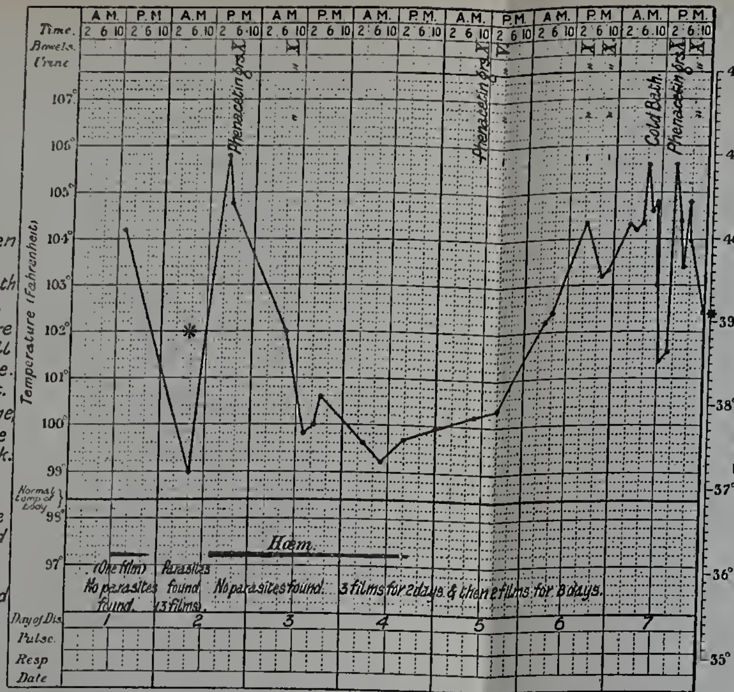
Under the care of
Dr Hearsay.

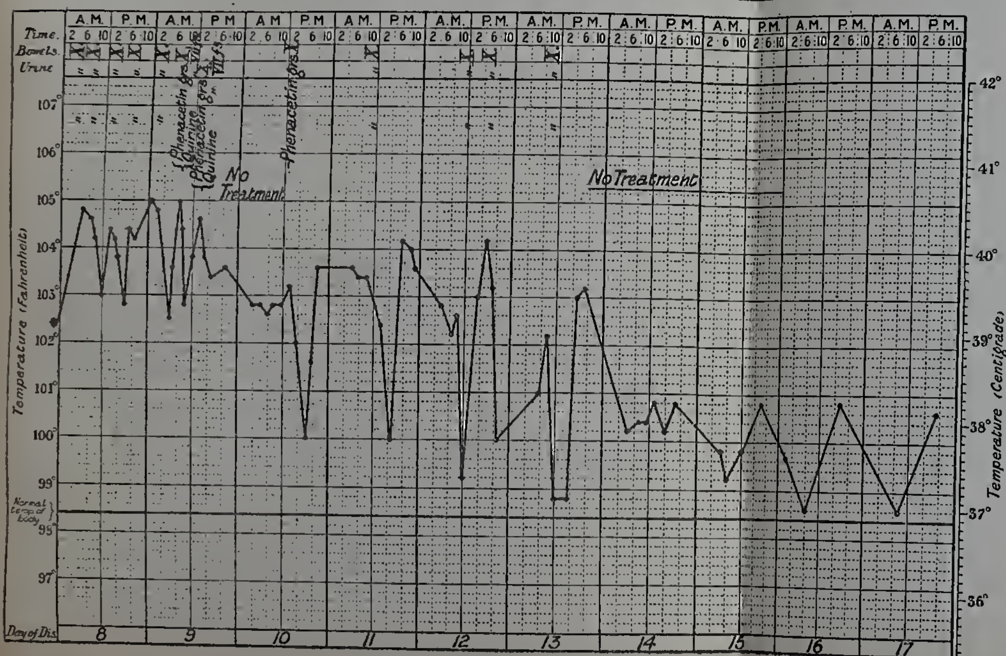
Name O.

NOTES OF CASE

Previous attack eleven months before.
Had enjoyed good health between the attacks.
For three days before this attack, was unwell & had much headache.
Was able to get about.
Had taken some quinine, the last dose (10 grs) the even before the attack.
Films during the first attack, no parasites.
Three films during the intermission, all showed parasites. In the last, noon 2nd day, only one was found & that showed signs of early sporulation.

RESULT Recovered.





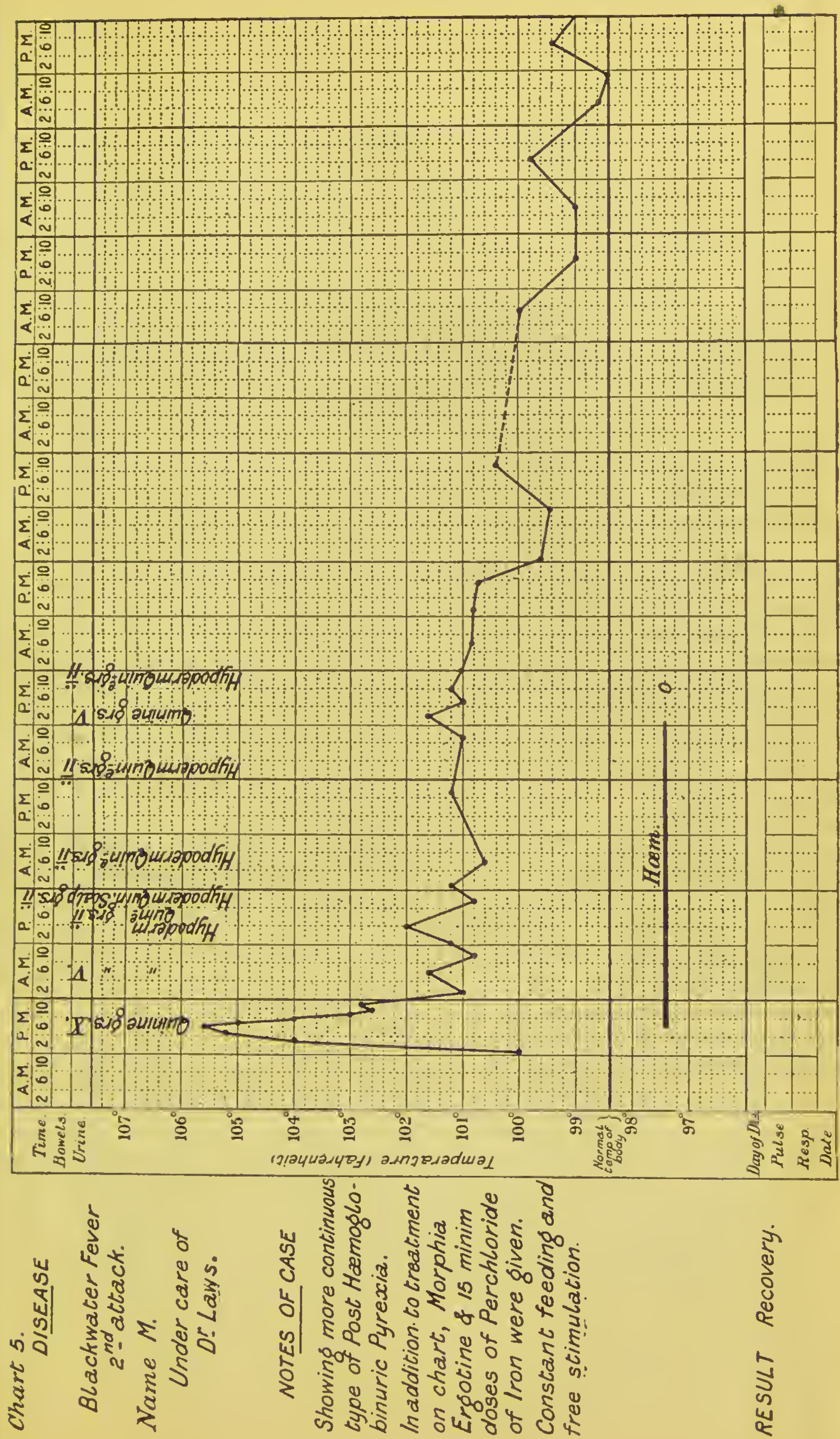


Chart 5.
DISEASE
Blackwater Fever
2nd attack.
Name M.
Under care of
Dr. Laws.
NOTES OF CASE
Showing more continuous type of Post Hæmoglobinuric Pyrexia.
In addition to treatment on chart, Morphia Ergotine & 15 minim doses of Perchloride of Iron were given.
Constant feeding and free stimulation.
RESULT Recovery.
Time
Bowels
Urine
Temperature (Fahrenheit)
107° 106° 105° 104° 103° 102° 101° 100° 99° 98° 97°
Normal temp of body
Day of Dis.
Pulse
Resp.
Date
A.M. P.M.
2 6 10
Quinine grs. X.
Quinine grs. V
Hypoderm Quin. grs. ii
Hæm.

Chart 6.

DISEASE

Blackwater Fever
1st attack.

Name B.

Under care of
Dr. Kerr Cross.

NOTES OF CASE

2½ years B.C.A.

Had been having fever off & on for 10 days with much vomiting.

Was taking quinine 15-30 grs. in a day, but not continuously.

Had temperatures of 101°F. on the 2 days before the attack.

No definite rigor at onset but one about 10 hours after.

No complications but convalescence slow.

Had crescent about 12 days after. No parasites found in attack.

RESULT Recovery.

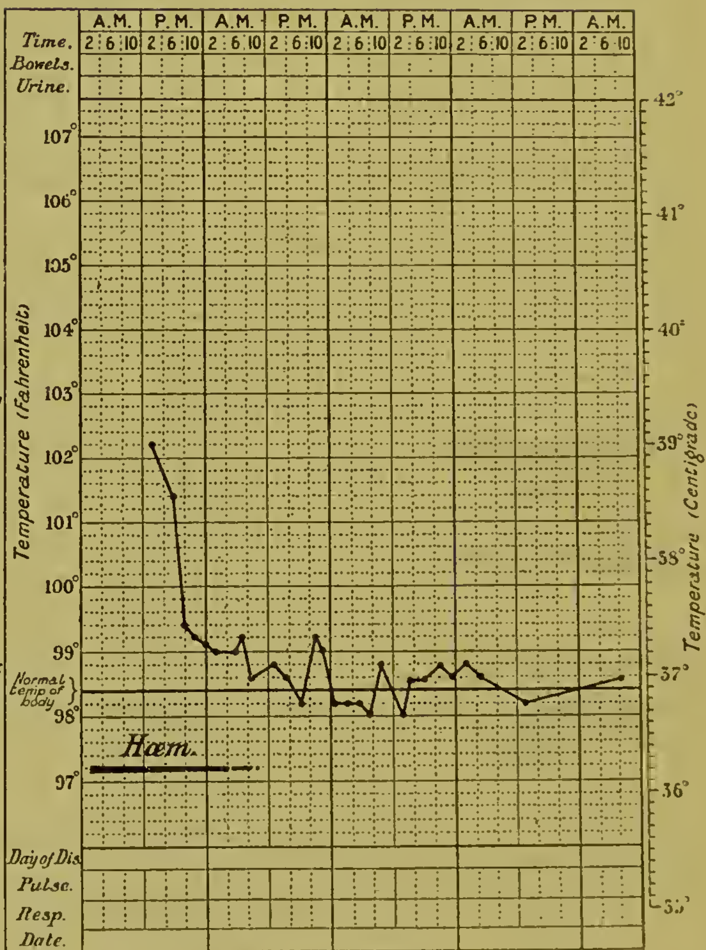


Chart 7.
DISEASE

"Blackwater Fever"

Name C.S.

Under the care of
Dr. Hearsay.

NOTES OF CASE

Sikh. Anæmia and enlarged Spleen.

The case is remarkable for the very slight disturbance in temperature during the period of Hæmoglobinuria.

There was low continued fever before, during, & after the Blackwater.

No parasites found in films taken during & after the Blackwater Period.

Treatment:–
Bicarbonate of Soda & Liq. Hyd. Perchlor.

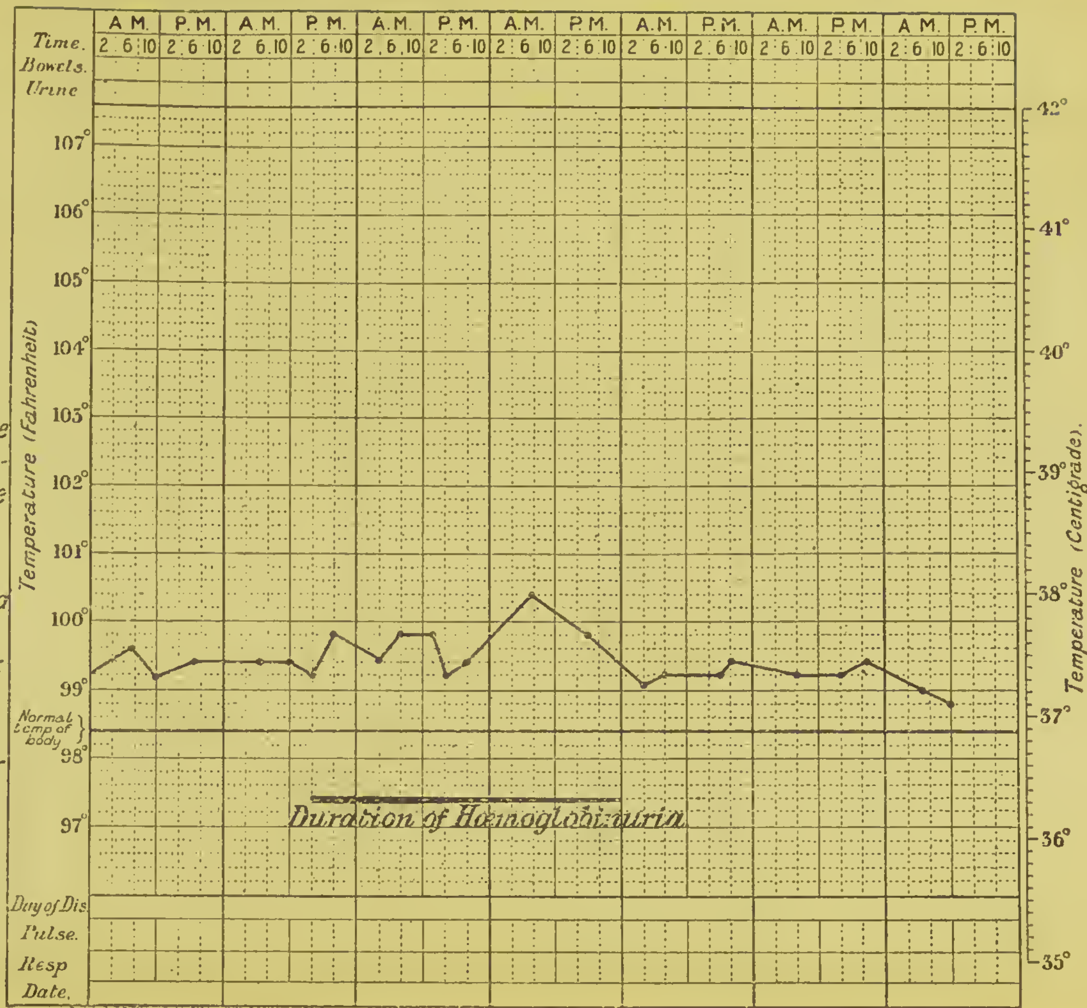


Chart 8.

DISEASE

Blackwater Fever
1st attack.

Name C.
Under the care of
Dr Hearsay.

NOTES OF CASE

Had been having "fever" off & on for some time. Resident in Shire Highlands & only left there 2 days before attack. Appeared in fair health day before attack, but at night his temperature was up & he took X grs. quine. Rigor initial. Moderate vomiting.

Treatment:—
Sodium Bicarbonate, & Liq. Hydrarg. Perchlor.
No parasites found.
Pigmented Leucocytes.

RESULT Recovery.

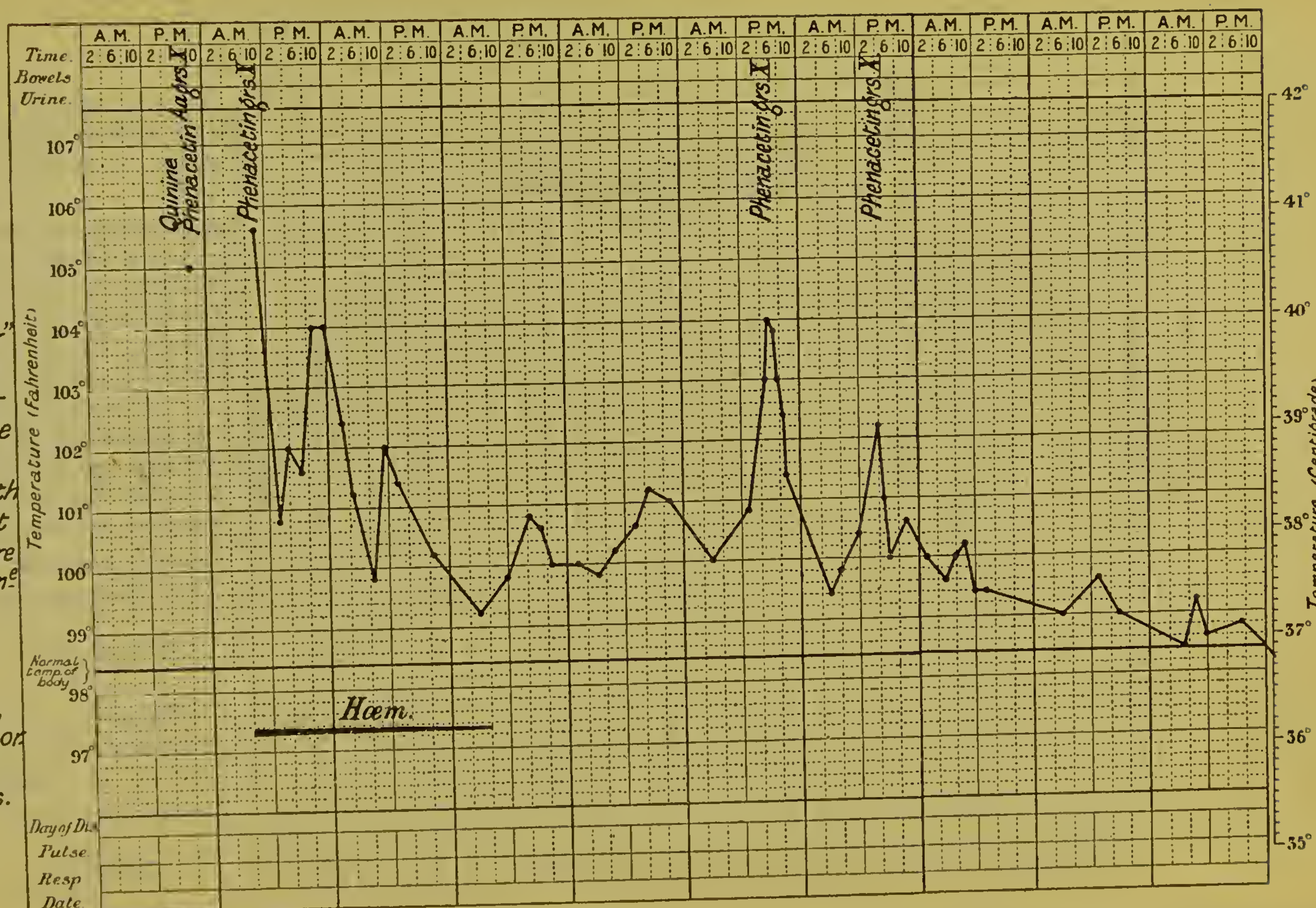


Chart 9.

DISEASE

Blackwater Fever
1st attack.

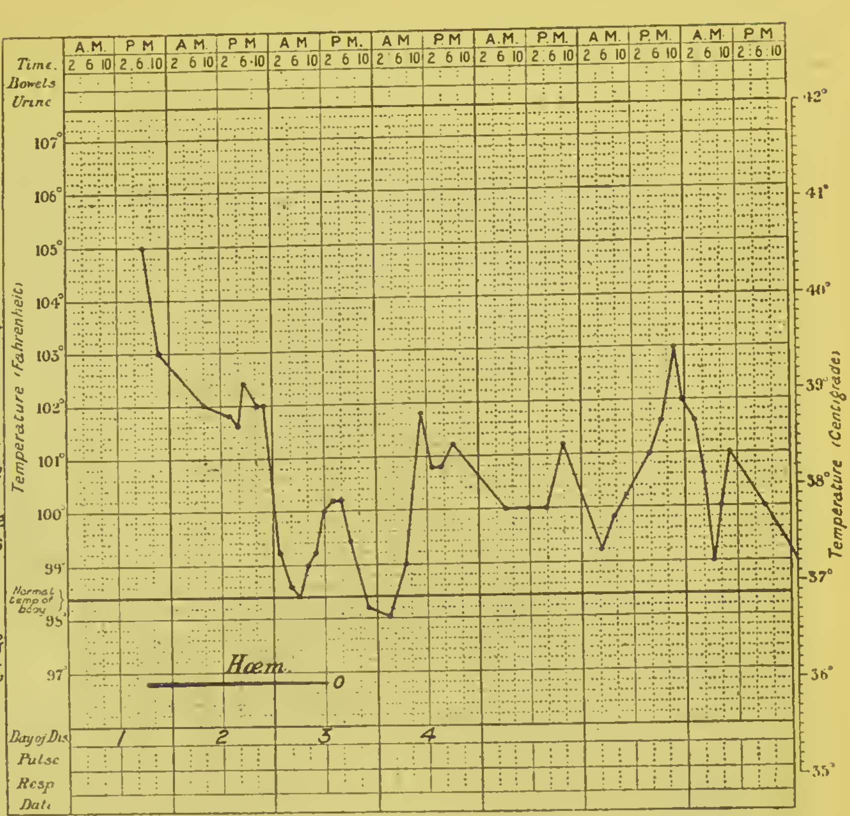
Name S.

Under care of
Dr Gray.

NOTES OF CASE

3½ years in B.C.A. Had very little fever after 1st year, been most of the time in Angoni & Shiré Highlands.
Not a quinine taker, but took 5 grs. rather more than a week ago.
"Fever" the day before the attack, as well as the same day.
Initial Rigor.
Treatment:-
Liq. Hydrarg. Perchlor. & Sodm. Bicarb. at first, & then Terebine.

RESULT Recovery.



DISEASE

Blackwater Fever
2nd attack.

Name S.

Under the care of
Dr Hearsay.

NOTES OF CASE

Previous attack 4 months ago. Since then has had good health.
Fever for 3 hours every day.
Last quinine grs. X, 12 hours before attack, & Antipyrine grs. V, 4 hours before.
Initial Rigors.
Treatment:-
Sodm. Bicarb. & Liq. Hydrarg. Perchlor.

RESULT Recovery.

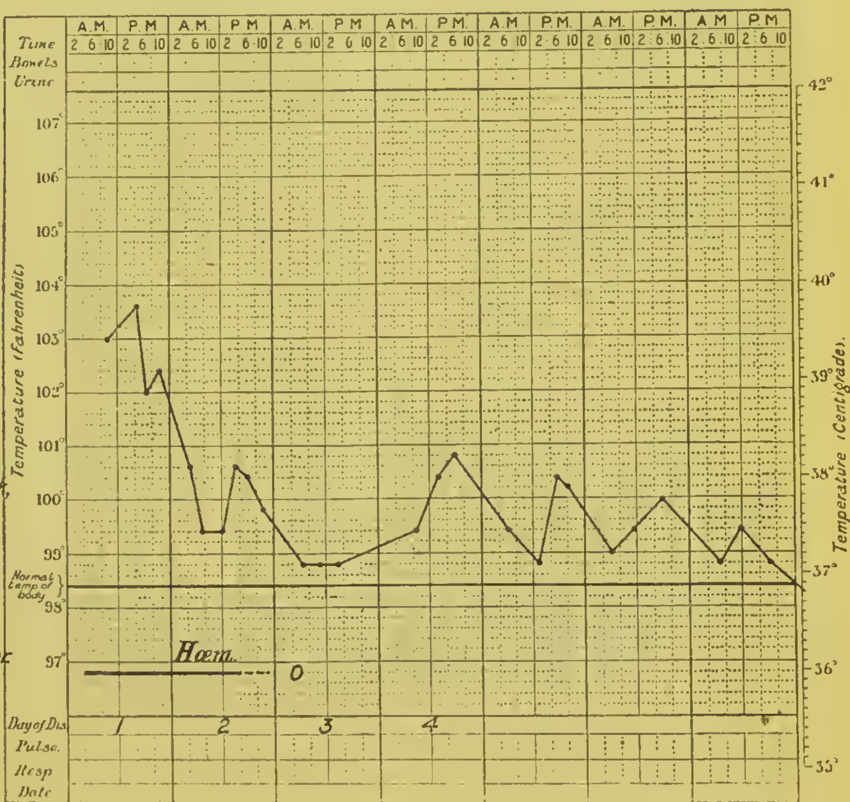


Chart 10.

DISEASE

Blackwater Fever
1st attack.
Hyperpyrexia.

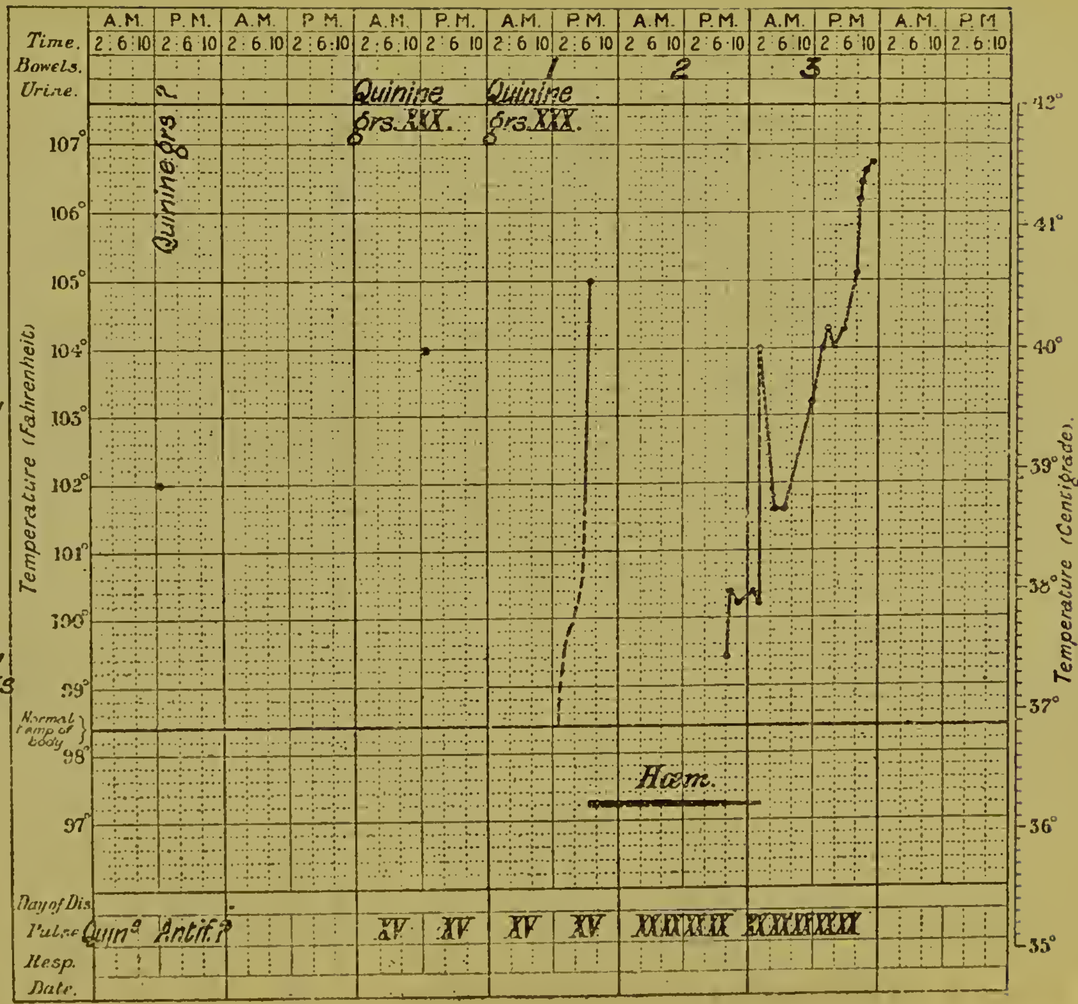
Name R.B.
Under care of
Dr. Mac Vicar.

NOTES OF CASE

Nine years in B.C.A.
Strong, full-blooded man.

Fever for 3 days, but felt better on 2nd day & was able to travel.

In addition to Quinine, digitalis & stimulants freely administered.



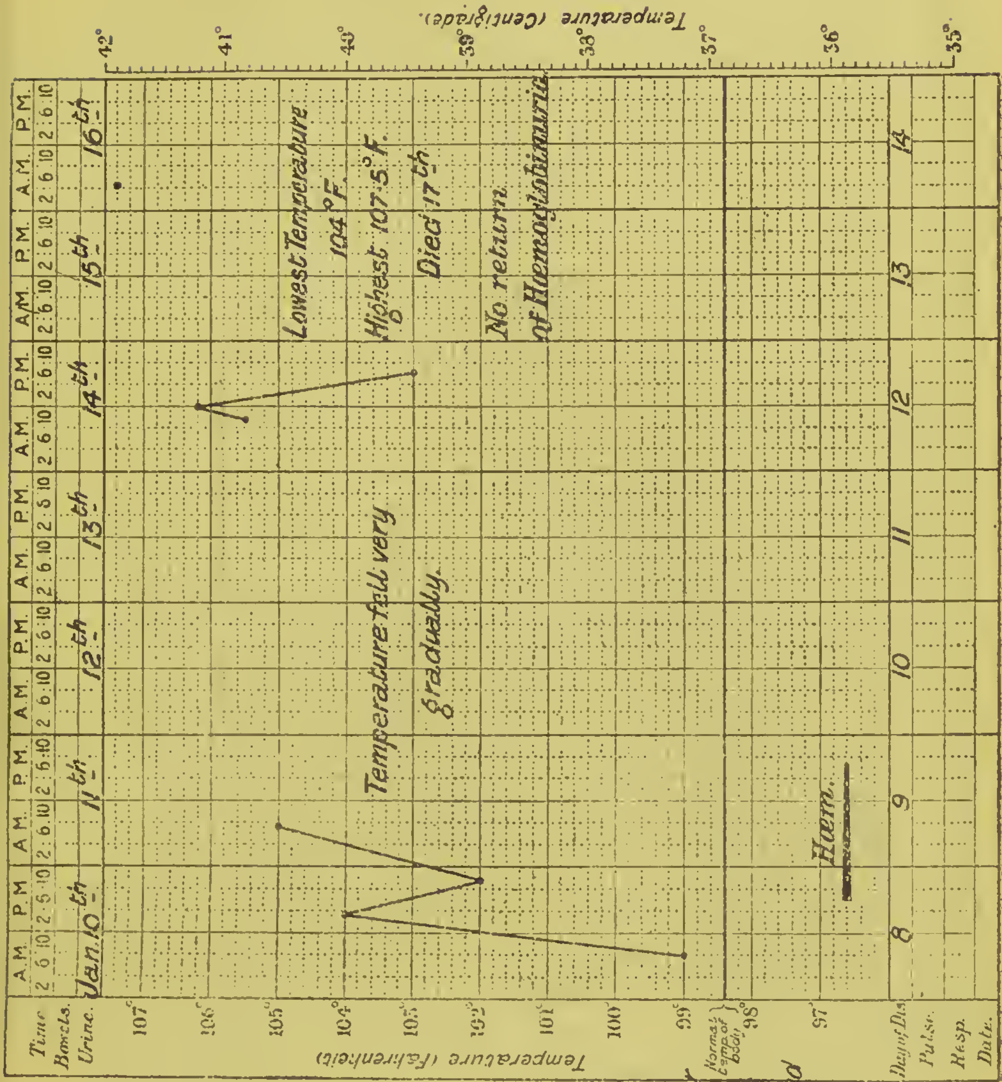


Chart II.

DISEASE

Blackwater Fever
Hyperpyrexia.

Name J.B.

Under care of M.O. Blantyre Mission.

NOTES OF CASE

Had Blackwater Jan. 3rd & 4th under 48 hrs. Temperature 104° fell about a degree daily from 5th. On 10th (M) 99°F. Rigor in afternoon & again passed Black-water. Urine cleared in about 24 hours. Temperature was never normal but fell gradually. From 14th–17th was treated with every available antipyretic. Cold bath alone had any success.

RESULT Died.

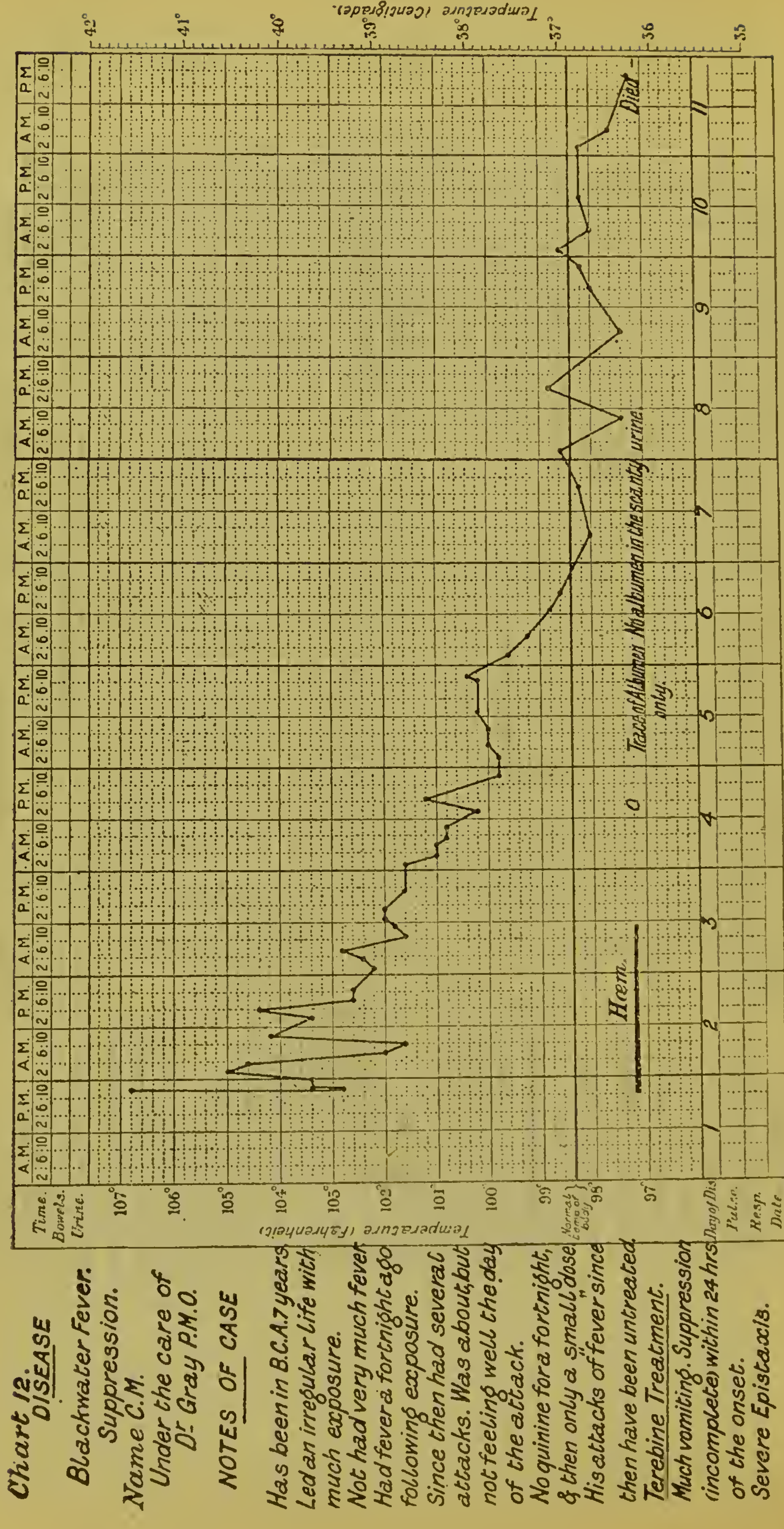


Chart 12.
DISEASE
Blackwater Fever.
Suppression.
Name C.M.
Under the care of
Dr Gray P.M.O.
NOTES OF CASE
Has been in B.C.A. 7 years.
Led an irregular life with
much exposure.
Not had very much fever.
Had fever a fortnight ago
following exposure.
Since then had several
attacks. Was about, but
not feeling well the day
of the attack.
No quinine for a fortnight,
& then only a small dose.
His attacks of fever since
then have been untreated.
Terebine Treatment.
Much vomiting. Suppression
(incomplete) within 24 hrs
of the onset.
Severe Epistaxis.
Temperature (Centigrade).
Temperature (Fahrenheit).
Time.
Bowels.
Urine.
Day of Dis.
Pulse.
Resp.
Date
Hæm.
Traces of Albumen only.
No albumen in the scanty urine.
Died

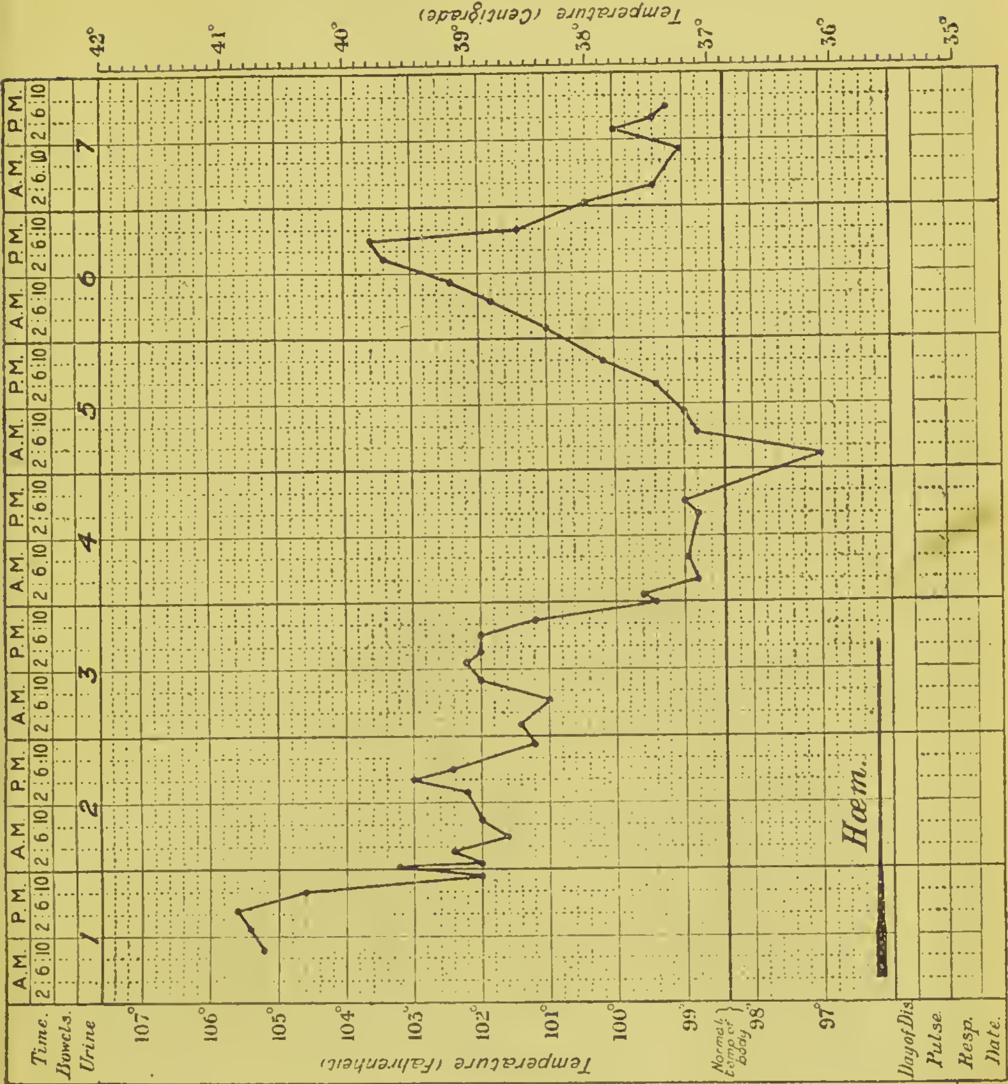


Chart 13.
DISEASE

Blackwater Fever.
Death from Lobar Pneumonia.
Name G
Under the care of
Dr. Kerr Cross

NOTES OF CASE

Had been in India & had fever there.
8 months in B.C.A., no definite attacks of fever, but malaise at times.
Had not been feeling well for over a week.
Onset sudden, during sleep, with severe rigor.
Very little vomiting.
Terebine Treatment.
Death from Lobar Pneumonia.

Chart 14.

DISEASE

Blackwater Fever
3rd attack.

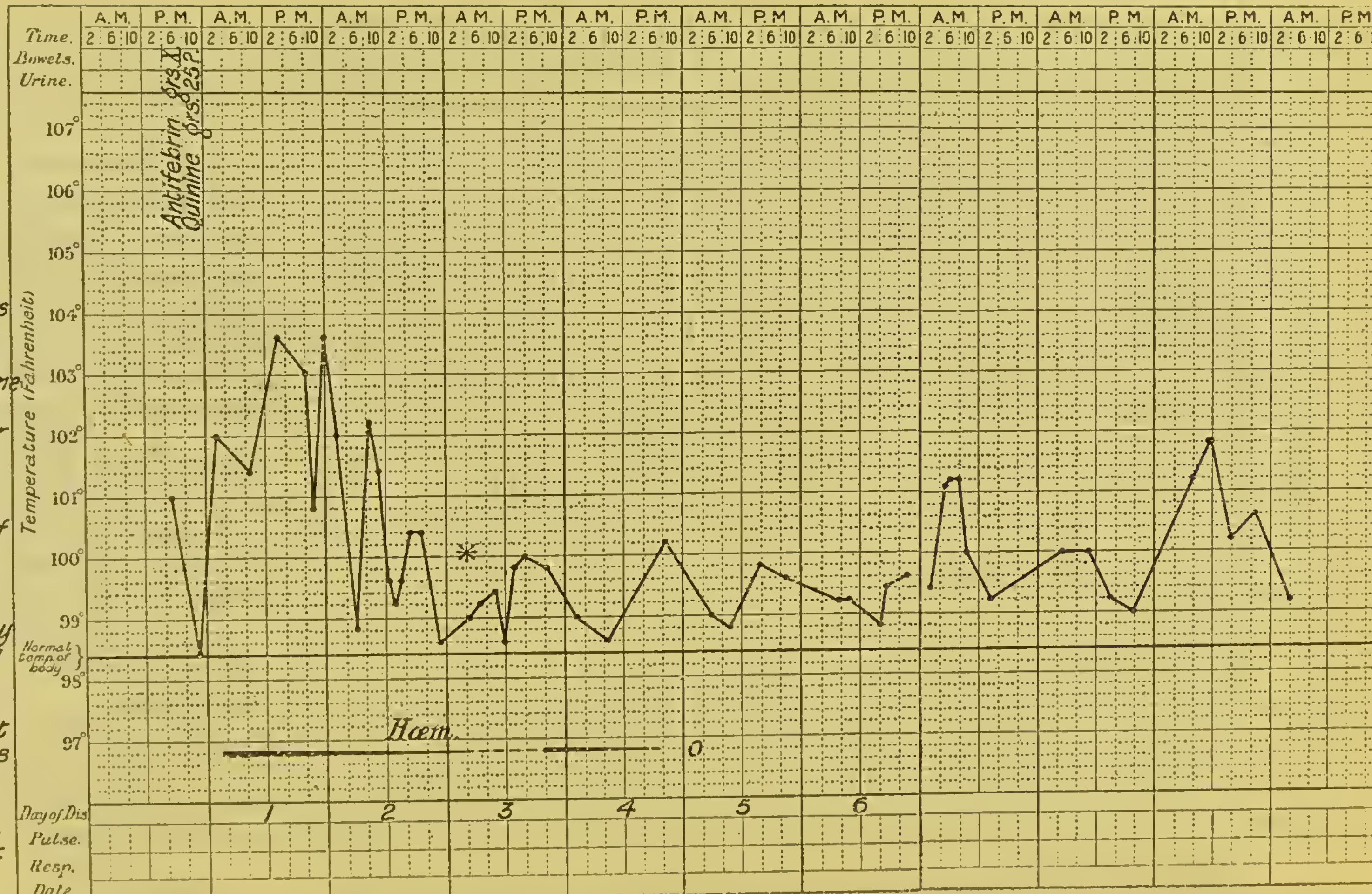
Name R.

Under care of
Dr Hearsay.

NOTES OF CASE

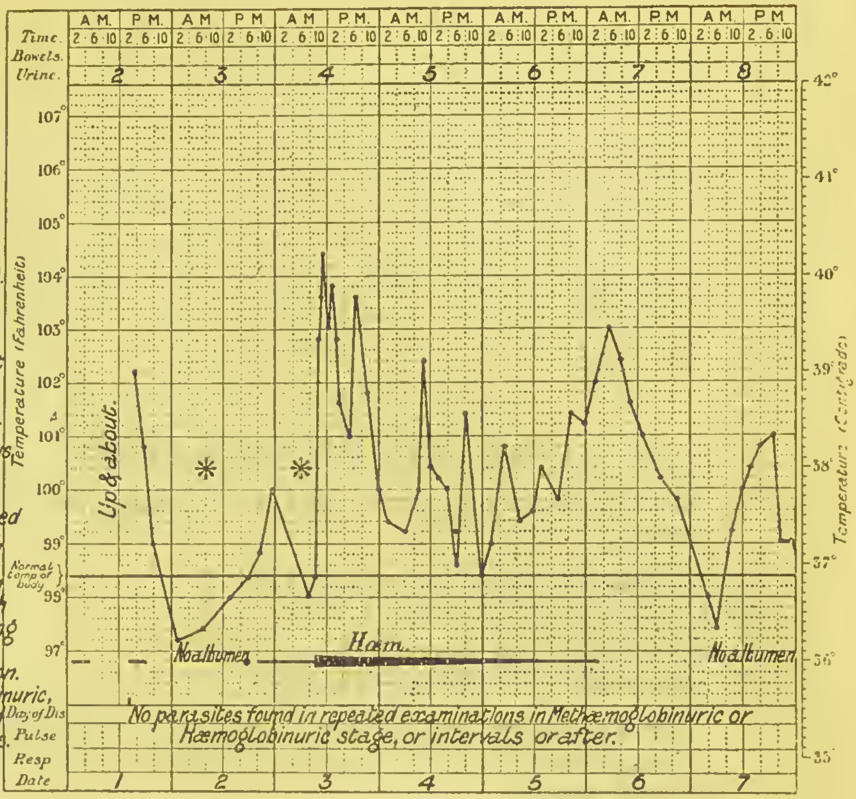
Previous attacks 18 months & 32 months ago.
Has had much fever.
Parasitic invasions sometimes large.
Day previous to Blackwater was up & about but felt ill in afternoon & went to bed. Took antifebrin & later a large dose of quinine ? 25 grs.
Rigor initial. Vomiting slight.
Urine was clearing rapidly on the 3rd day but again became quite dark in evening.
No parasites found, but pigd leucocytes in films on 3rd day.
Treatment:–
Bicarbonate of Soda,
& Liq. Hydrarg. Perchlor.

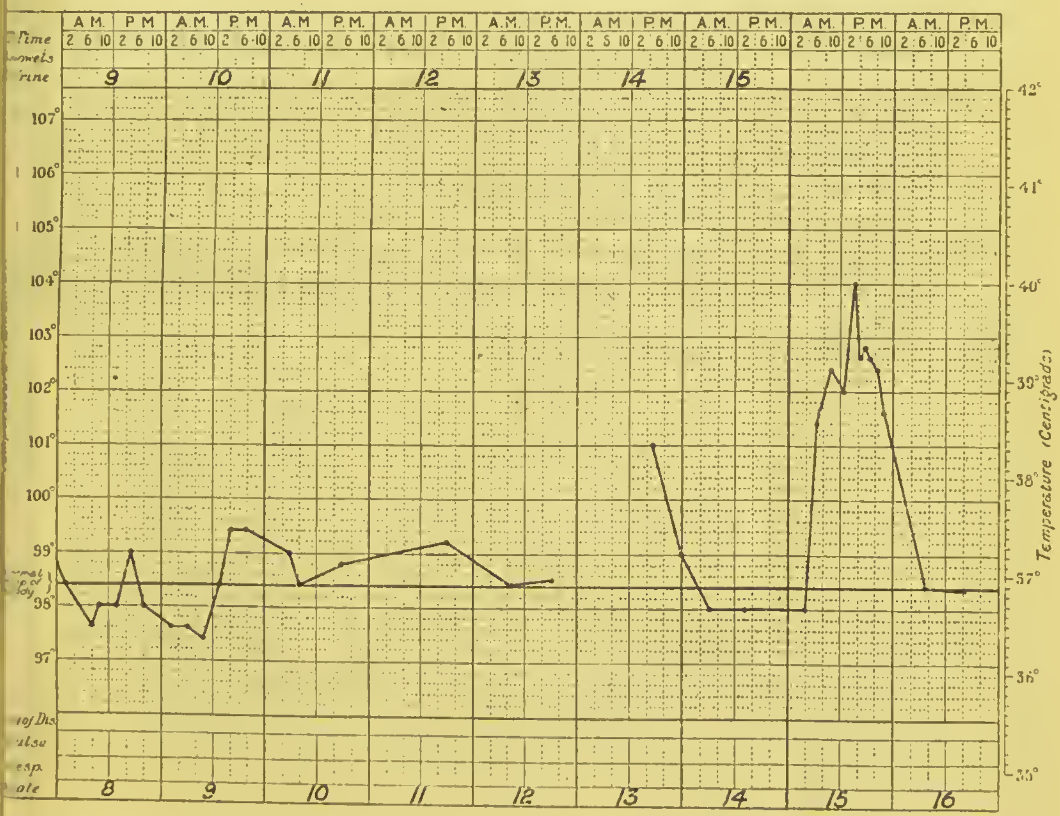
RESULT Recovery.



...rt 15.
. DISEASE
...ackwater Fever"
1st attack.
...e H.
...der the care of.
...LDr Gray P.M.O.
...TES OF CASE

...11 yr. 10 mths. in B.C.A.
... good deal of fever
...me time took fair
... of Quinine. Of late
...ken little, & the last
...was 3 or 4 days
...e onset.
...d "brown" urine in night
...had fever for 2 days
...clear in morning &
...nt out but had to
...n. In afternoon passed
...urine, Methæmoglobin,
...in cleared.
...ving afternoon again
.../ Methæmoglobin which
...ued till the following
...ng when there was a
...change in his condition.
...rine passed Hæmoglobinuric,
...k that it was estimated
...would persist 2½-3 days.
...Hepatic not Renal.





ILLUSTRATIVE URINE CHARTS.

URINE CHARTS, showing the rate per hour, in ounces, at which the urine is excreted.

A (1) corresponds to Temperature Chart 13.
A (2) corresponds to Temperature Chart 6.
A (3) Temperature Chart similar to 6. Not given.
A (4) corresponds to Temperature Chart 1.

These charts show an increase in the amount during the hæmoglobinuric period, followed by a drop to below normal as the urine clears, and a slow return to normal.

B. (Corresponding to Temperature Chart 8.) Merely slight increase in the rate during the hæmoglobinuric period. No marked drop as the urine cleared.

C. (Corresponding to Temperature Chart 2.) There is a decided fall in the amount passed in the first twenty-four hours; (?) indicating a tendency to early suppression, followed by a great increase in the second twenty-four hours, and a subsequent fall as the urine cleared.

The first fall was not due to *retention* of urine.

D. (Corresponding to Temperature Chart 12.) Suppression case. The amounts passed after the first twenty-four hours are too small to be indicated on this scale.

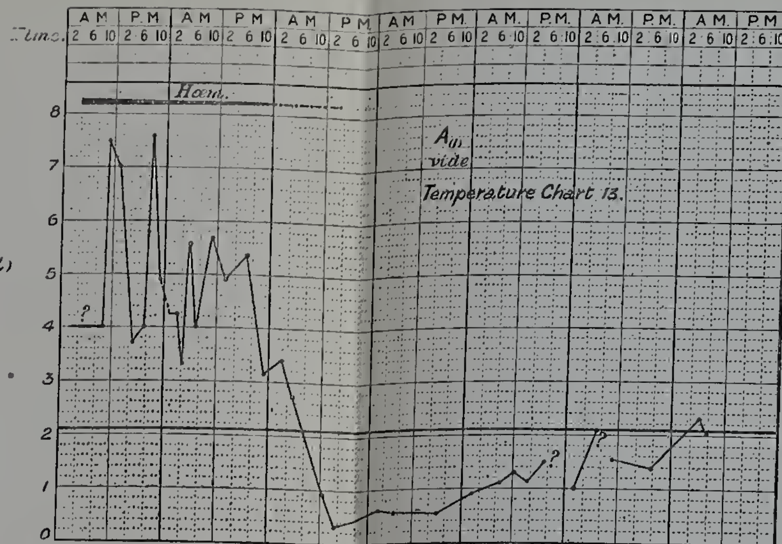
E. (Corresponding to Temperature Chart 15.)

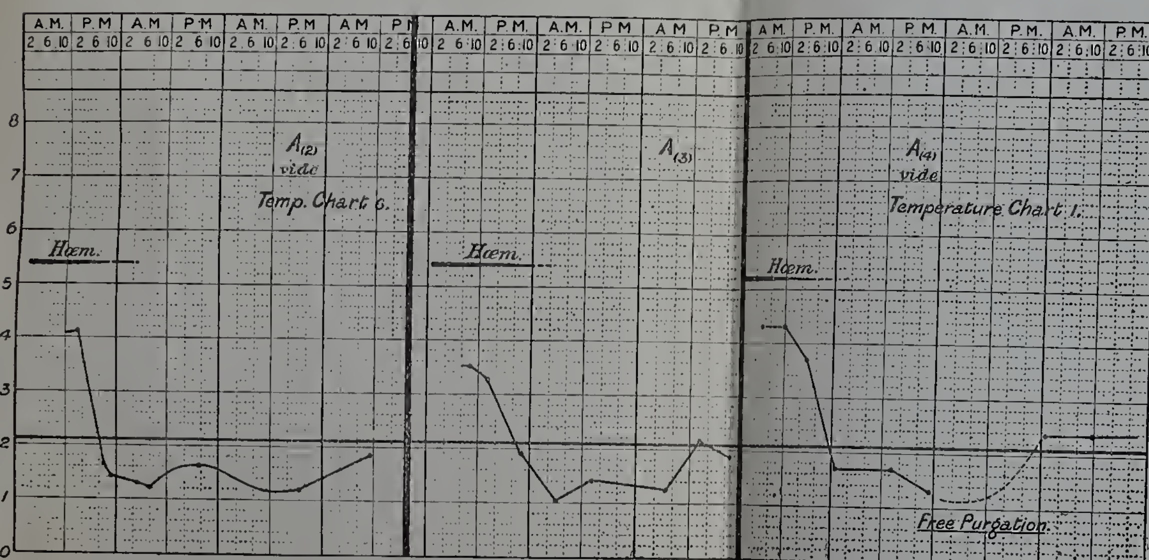
Urine Charts.

Indicating the rate of excretion of Urine in ounces per hour.

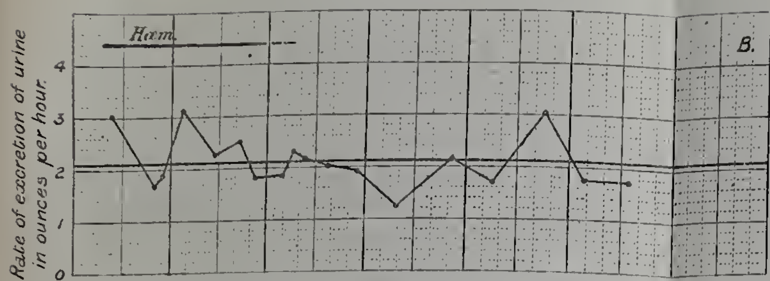
The thick line (horizontal) indicates the duration of the Hæmoglobinuria.

A



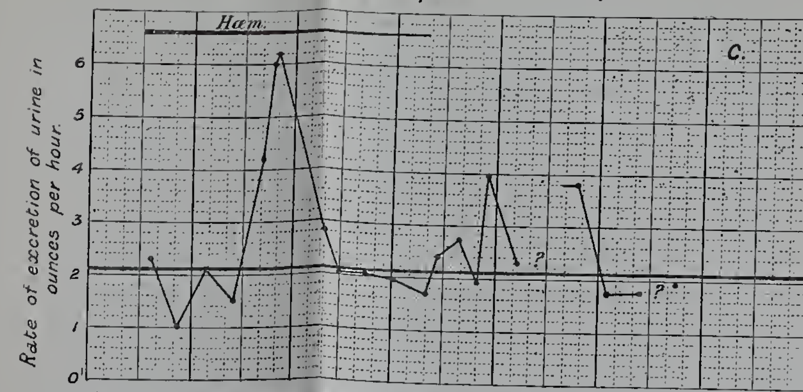


B. vide Temperature Chart 8.



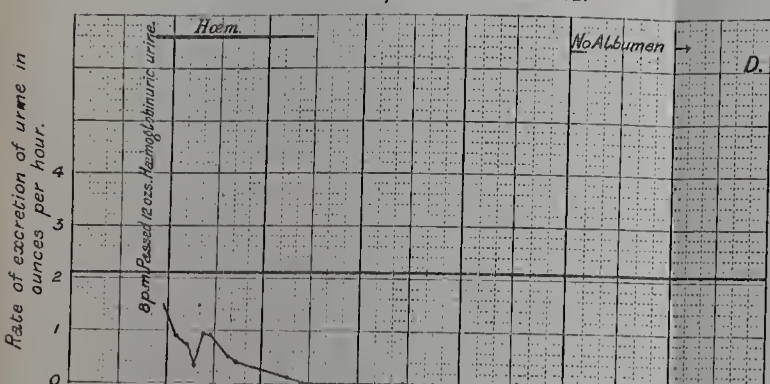
Slight increase in rate of excretion during the Hæmoglobinuric Period. No marked fall below the normal as the urine cleared.

C. vide Temperature Chart 2.



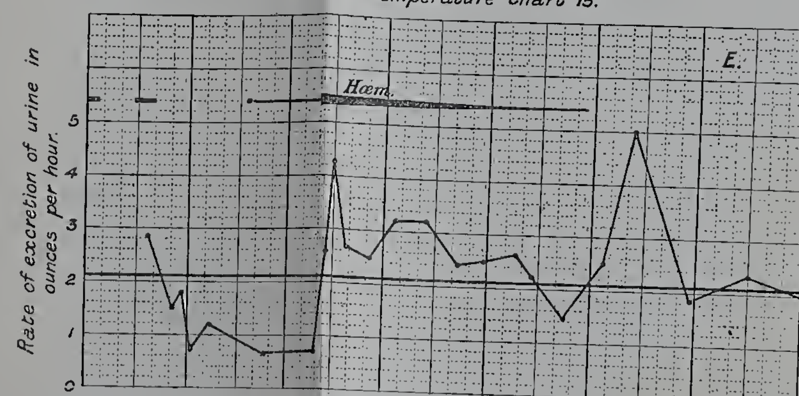
Early fall in the amount of urine excreted. During the time that the rate was low there was very frequent micturition. No retention. Great increase in the amount & rate of excretion followed this period.
No marked fall below normal as the urine cleared.
Subsequent increase in the rate of excretion. From more imperfect notes of other cases I gather that such a subsequent rise is common.

D. vide Temperature Chart 12.



"Suppression Case." Twelve ounces were passed within half an hour of the first symptoms; after that, the rate was always below normal, & after the first 24 hours very little was passed.
The patient died after 10 days.

E. vide Temperature Chart 15.



Previous to the thick horizontal line the urine contained Methæmoglobin at the times corresponding to the thinner horizontal lines.
The rate of excretion at first high, fell as the urine cleared; it did not rise with the onset of Methæmoglobin again, but did with the onset of Hæmoglobinuria.
Slight fall as the urine cleared, followed by a marked subsequent increase.

ERRATA.

REPORTS TO THE MALARIA COMMITTEE, 1899–1900.

Malarial and Blackwater Fevers of British Central Africa.)

age 24, line 22. *Omit* "Report I."
,, 26 ,, 29. *For* "plasterer" *read* "planter."
,, ,, lines 41 and 43. *For* "Inpimbe" *read* "Mpimbe."
,, 27, line 2. *Omit* "Case I."
,, 28 ,, 2. *For* "Case II" *read* "Case III"; *omit* "*vide* also Chart X."
,, 30, lines 28 and 37. *For* "Bright's" *read* "Weigert's."
,, 31 ,, 3 and 37. *For* "K_4TeCy_{76}" *read* "K_4FeCy_6."
,, 32, line 13. *For* "narrow" *read* "marrow."
,, 33 ,, 2. *For* "Case III" *read* "Case IV"; *omit* "*vide* also Chart VII."
,, 36 ,, 2. *For* "Case IV" *read* "Case V"; *omit* "*vide* also Chart VIII."
,, 38 ,, 12. *For* "Chart IV" read "Chart VIII."
,, ,, ,, 18, columns 4 and 5. *For* "H" *read* "No."
,, ,, ,, 19 ,, ,, ,, ,,
,, ,, ,, 21 ,, ,, ,, ,,
,, ,, ,, 22 ,, ,, ,, ,,
,, 40 ,, 6. *For* "Case V" *read* "Case II"; *omit* "*vide* also Chart IX."
,, 41 ,, 42. *For* "Chart V" *read* "Chart VI."
,, 62 ,, 41. *For* "Case I" *read* "Case II."
,, 63 ,, 25. *For* "Case II" *read* "Case III."
,, 66 ,, 10. *For* "Case I" *read* "Case II"; *omit* "of our previous report."
,, 69 ,, 13. *For* "Case I" *read* "Case II."
,, ,, ,, 15. *For* "Case III" *read* "Case IV."
,, ,, ,, 22. *For* "Case II" *read* "Case III."

ROYAL SOCIETY.

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SIXTH SERIES.

CONTENTS.

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1902.

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CONTENTS.

REPORTS, &c., FROM MESSRS. STEPHENS AND CHRISTOPHERS, BENGAL.

"The Relation of Malarial Endemicity to '*Species*' of Anopheles." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received October, 1901.

1. *Definition of Endemicity.*

It has always been recognised that in a particular country certain districts are more malarial than others. If we proceed to ascertain to what extent malaria prevails in a district we may do so in several ways—

(1.) We may consult the hospital statistics for admissions for malaria.

(2.) We may determine to what extent enlargement of the spleen prevails.

(3.) We may determine by actual blood examination how many individuals have parasites in the peripheral circulation. More especially does the parasite rate in children, as pointed out by Koch, give a definite and true index of endemicity, which may be used in the comparison of one locality with another.

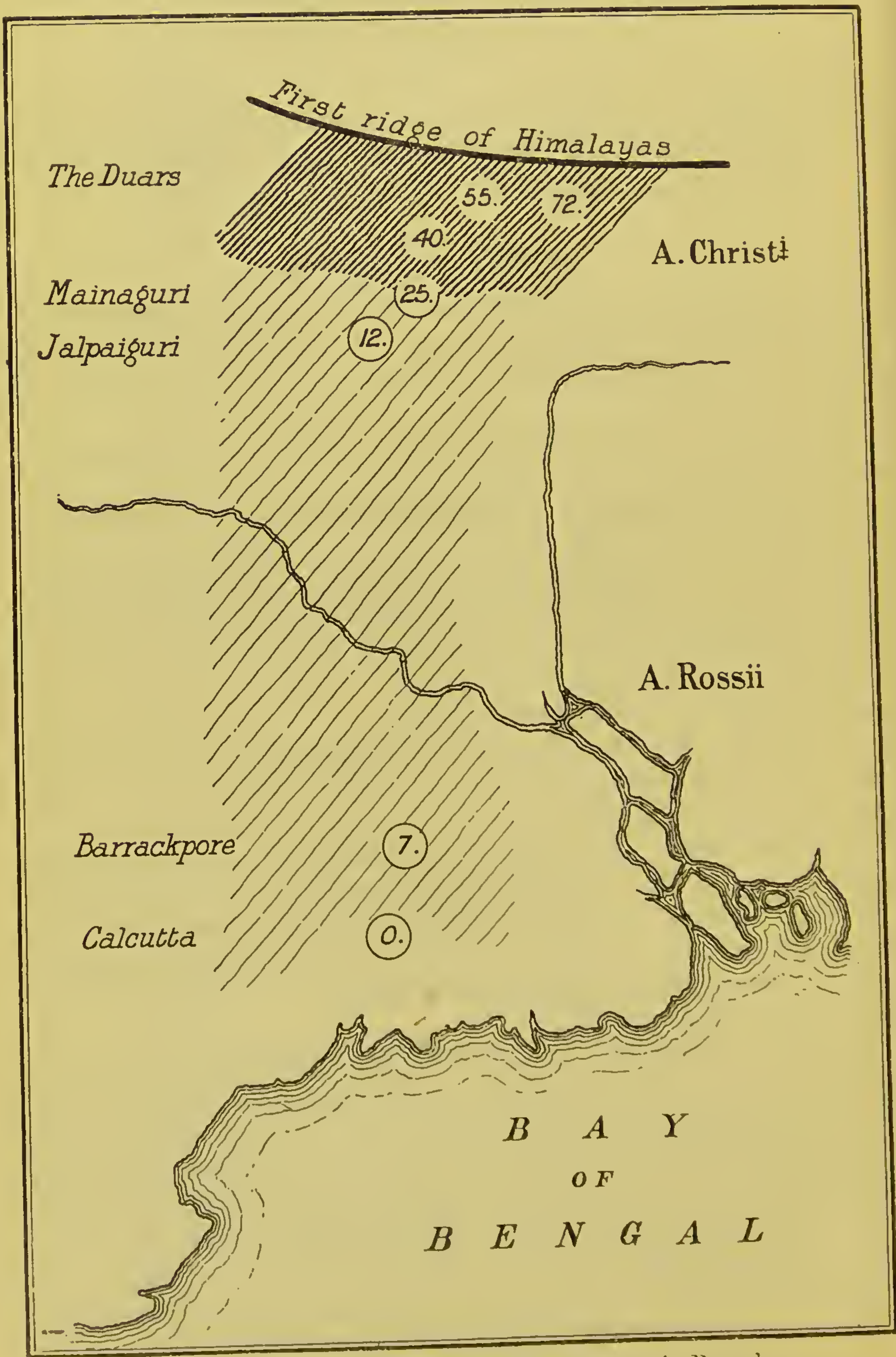
To this method we would add, as a complementary one, the determination of the percentage of infected Anopheles, as giving the actual risk of infection in a district.

These methods of determining the endemicity are by no means of equal value. The two first we shall further discuss in another paper. We may say shortly, however, that the first is of quite secondary importance and open to grave errors, whilst the second, though of value in districts where blood examinations cannot be made, yet is also open to serious error.

It is in the third sense that "endemicity" or "endemic index" is used by us in this paper. The endemic index, then, we may take to be the percentage of infected children (under 10 years of age) in any district, and is the truest test of the infection present and the liability of immigrants to contract malaria. In this way Koch has shown the endemicity of malaria to vary in the Dutch East Indies from 0 per cent. to 100 per cent. Our own researches and those of Annett and Dutton have shown that in West Africa the endemicity of the various districts is uniformly very high—20 per cent. to 100 per cent.

2. *The Malarial Endemicity of Bengal.*

By the examination of a number of children from various districts we have determined the endemicity of representative portions of Bengal. The following map and table will at once show how, in pro-



Sketch Map to show Variation of Endemicity in Bengal.

Table I.—Showing Variations in Endemicity in Bengal.

Locality.		Endemic index.	Number of children examined.
Calcutta	Phoolbagan Road	0 per cent.	57
	Hastings	0 "	84
	Kidderpore	0 "	50
Plains of Bengal	Barrackpore	7·7 "	26
	Belghurria	7·4 "	27
	Jalpaiguri	12·7 "	86
	Mainaguri	25 "	40
Duars	Rangamutty	43 "	72
	Nagasuri	55·5 "	27
	Ghatia	72 "	25

ceeding from Calcutta northwards till the foot of the Himalayas was reached—a distance of some 300 miles—we passed from a region the endemic index of which was 0 per cent., through regions with increasing indices of endemicity, till at the foot of the hills, in a district known as the Duars, a very high degree of infection was reached, 40 per cent. to 72 per cent., as high, indeed, as that found by us in West Africa. We have, then, a region, not above 300 miles in latitude, subject to almost identical climatic influences, with an endemic index varying from 0 per cent. to 72 per cent.

3. *The Cause of the Variation in the Endemicity of Bengal.*

As just mentioned, the climatic influences are very similar throughout the district. A high degree of atmospheric humidity, a very uniform high temperature—86° to 90° in the shade—and the presence of abundant surface water. In these respects we could see no essential difference between regions of low and those of high endemicity. We are left, then, with the following possible explanations of the variation :—

a. The number of Anopheles present.
b. The effect of the importation of non-immunised individuals.
c. The "species" of Anopheles in different districts are not the same.

a. The Number of Anopheles Present.—The portions of Calcutta investigated by us were portions of the native town, in both central and outlying districts, which, from their squalid nature, appeared the most likely to possess high fever rates. Here we had, at first sight, all the conditions which, from their similarity to those of West Africa, would have led us to expect a high endemic index. The temperature

during some months had been as high as 86° to 90° in the shade during the day, and the atmospheric humidity was as great as that of the most malarious districts of the West African Coast.

The houses were in no essential particular different from those in Africa, nor was the social condition of the inhabitants higher.

Anopheles were everywhere present, and in some quarters were extraordinarily abundant. Even in Africa we have never seen larvæ so abundant or adult insects so readily caught.

We had, then, here apparently all the essential points of an African village reproduced, and we naturally expected a considerable degree of child infection. But this proved not to be the case.

(1.) An examination of the children of several of the worst districts and those with most Anopheles was completely negative. In all, 141 children were examined throughout June, July, and August without a single parasite being found by us.

We may note that, though during this time many cases of enlarged spleen were admitted into the different civil hospitals of Calcutta and diagnosed as malaria, yet parasites were only found with the greatest rarity. The only hospitals in which parasites were readily found by us were the military hospitals.

(2.) An examination of the Anopheles from these quarters of Calcutta was also completely negative. In all, 324 Anopheles were dissected, and neither sporozoits nor zygotes were found by us.

Table II.—Showing Absence of Malarial Infection in Calcutta.

District of Calcutta.	Endemic index.	No. of children.	Sporozoit rate.	No. of anopheles.
Phoolbagan Road	0 per cent.	57	0 per cent.	200
Hastings...	,,	77	..	5
Fort William........	,,	7	0 per cent.	116
Kidderpore..........	,,	50	..	8
Total...........	..	191	..	329

Briefly, we may say that in Calcutta we had in June, July, and August an extraordinary number of Anopheles with an endemic index of 0°.

A very different state of affairs were present in the Duars. Here, though frequently we had great difficulty in collecting sufficient Anopheles to enable us to determine the sporozoit rate, the amount of malarial infection was very large. Whereas in Calcutta, in two districts at least, we were able to collect in an hour 50 or more Anopheles, in Nagasuri, in the Duars, with an endemic index of 55 per

cent., we collected during many days and with difficulty only 39 specimens.

It is evident, then, that the mere number of Anopheles present cannot be the cause of the great variation in the endemicity of Bengal.

b. The Effect of the Importation of Non-immunised Individuals.—Koch has shown how the importation of fresh coolies from the non-malarial districts is responsible for an increase in the fever incidence, and that an immunity is later developed in these, so that a gradually diminishing fever incidence ensues, until a new set of coolies is again imported.

No large immigration occurs in the district under consideration, except on the tea plantations of the Duars. As this district is the one with the highest fever rate, it is possible that the extremely high endemicity may be partly due to this cause. The endemic index taken as the test of each district was, however, determined from the coolies coming from the plains who dwelt in separate villages from the hill coolies. Moreover, the coolies from the plains were for the most part long resident in the district, and most of the children examined by us were either born in the district or had lived nearly the whole of their life there.

There was also already a marked increase in endemicity (25 per cent.) at Mainaguri, about 30 miles from the Duars. Here there is no immigration, and the inhabitants are all long resident in the district.

It seems probable, then, that over and above the effect of the immigration of strangers, there is a real and marked increase in the endemic index in this district.

c. The Species of Anopheles in Bengal.—A closer examination of the Anopheles occurring in Bengal proved that we were dealing with a considerable number of species. It also became evident that the distribution of certain species coincided with areas of high endemicity, whilst other species occurred and even existed in profusion where very little infection was present.

The species of Anopheles found by us were six in number : *A. Rossii* (Giles), *A. fuliginosus* (Giles), *A. sinensis* (Wied), sub-sp. *nigerrimus* (Giles), *A. Lindesayi* (Giles), and two species new to India. These latter are *A. metaboles* (Theobald) and *A. Christophersi* (Theobald).

It was found that in many parts of Calcutta one species only occurred from June to August, namely *A. Rossii* This species was present in enormous numbers.

In certain outlying portions of Calcutta, and in the country around Calcutta, two other species were found somewhat sparingly, namely, *A. fuliginosus* and *A. sinensis*, sub-sp. *nigerrimus.*

These three species appear to be present everywhere in the plains of Bengal. They were the only species found by us until the foot of the mountains (Duars) were reached. *A. Rossii* was also found by us at a

height of 5000 feet, *A. fuliginosus* at 800 feet, and *A. nigerrimus* at 1200 feet North of Jalpaiguri, about 30 miles from Duars, *A. metaboles* was found breeding scantily. This species was found to increase in numbers as we passed northwards, and it extended high into the hills (5000 feet).

The district known as the Duars is a strip of land extending for some hundreds of miles along the foot of the Himalayas. It is a gently sloping tract of from 800 feet to 1200 feet above the sea, and abounding in small streams. In this narrow strip another new species, *A. Christophersi*, was found in abundance by us. This is a very small mosquito and resembles to some extent *A. funestus*. We have never found this species in any of the districts visited by us, except in the Duars.

A. metaboles was in the Duars also a very common mosquito, judging by the large numbers and wide distribution of larvæ.

Our observations so far then can be stated briefly as follows :—

Table III.—To show Relation of Species of Anopheles to Endemicity.

Locality.	Species present.	Endemic index.
Calcutta { Phoolbagan Road....	*A. Rossii.*	0 per cent.
Calcutta { Hastings	*A. Rossii.* *A. fuliginosus.*	0 per cent.
Plains of Bengal..............	*A. Rossii.* *A. fuliginosus.* *A. nigerrimus.*	From 7 to 12 per cent.
Duars	*A. Christophersi.* *A. metaboles.* *A. Rossii.*	From 40 to 72 per cent.
Hills (5000 feet)..............	*A. metaboles.* *A. Rossii.* *A. Lindesayi.*	0 per cent.

Such facts led us to question whether considerable variation did not exist in the power of different species of anopheles to act as host to the malarial parasites, and whether the endemicity in any district might not, to a large degree, be dependent on which species of anopheles occurred there.

We therefore wished to determine for each of the species whether, in the first place, it was a carrier of malaria. Unfortunately, in the Duars we had few facilities for feeding, and the evidence for some of the species is not conclusive. The following experiments and observations show, however, that *A. Rossii* appears to be not a carrier, or in any case a very poor carrier, that *A. Christophersi* is a good carrier, and that *A. fuliginosus* and *A. nigerrimus* are doubtful as carriers.

A. Rossii.—The fact that this species can occur in such profusion as it did in Calcutta without a corresponding degree of infection, is in itself strongly suggestive that this species is a harmless one.

We may note also that Major Ross was unable to cultivate human malaria in Calcutta, where he must have used *A. Rossii*, but that he succeeded in doing so with some specimens of Anopheles up country.

Our own experiments with *A. Rossii* have not been more successful. The insects used by us were not reared from larvæ, but caught already fertilised in sheds and houses. Any possible infection in these would in no way vitiate the experiment, and by this means we avoided the risk of non-fertilisation or other influences which render the use of bred insects uncertain.

The following table gives the result of our experiments with *A. Rossii* :—

Table IV.—To show Result of Feeding *A. Rossii* upon Cases of Malaria.

Case.	Date of feeding.	Date examined.	Result.	Number examined.
Simple tertian ...... Numerous large forms.	July 20, 21, 22, 23	July 25	Negative	8
Crescents .... Very abundant throughout.	July 21, 22, 24	July 26	Negative	5
Simple tertian ...... Numerous large forms.	July 22, 23........	July 25	Negative	6
Simple tertian .... Fairly numerous large forms.	July 24, 26........	July 27	Negative	9

As *A. fuliginosus* and *A. nigerrimus* seemed to be the only alternative carriers of malaria in the regions of low endemicity around Calcutta, as many specimens as possible were examined. In an accompanying paper we have shown that though *A. nigerrimus* is a very common species breeding extensively over large tracts of marsh, yet that in houses it was seldom caught. The difficulty of obtaining specimens prevented our determining whether this species carried sporozoits. A small number (four) caught in houses were fed every night for five nights on a case which had crescents in large numbers. These were examined on the fifth day, but were negative. Eight specimens caught in houses were also negative.

A. fuliginosus were more abundant in houses, but still rather rare. Thirty-six specimens of *A. fuliginosus* were found negative. Two specimens were dissected on the fifth day, after feeding on a crescent case, but were negative.

A. Christophersi.—This species is undoubtedly a good carrier. Sporozoits were found in 4 out of 64 specimens, or 6·25 per cent. This rate is only a little lower than that frequently found by us in Africa.

A. metaboles.—From the difficulty of obtaining the adult insects, sufficient numbers were not examined to determine whether this species carried malaria. Eleven specimens from huts were negative.

It was hoped that sufficient specimens of the five species might have been examined in an area of high endemicity to give figures which would show the sporozoit rate of each species. We were, however, at the present time (August) unable to do so. We believed, however, that marked differences would be found, and we believed this to be the explanation of certain observations made by us in Africa. Thus Lagos had a sporozoit rate of only 3 per cent., while 50 miles up country a sporozoit rate of 50 per cent. occurred. In Lagos we were dealing almost exclusively with *A. costalis*, while in the latter place the common species was *A. funestus.*

Before drawing the conclusion that the endemicity of a district is dependent on the species of Anopheles present, much more extended observations than those we have now put forward are required. Even a district like Bengal is in reality so extensive that generalisations are apt to be hasty. We can, however, draw the following conclusions, and they show that the question of "species" is a very important one, and one that may possibly be an important cause in bringing about such varying degrees of endemicity as are found in different districts.

Conclusions.

1. That *A. Rossii* occurs in Calcutta in June, July, and August, together with an endemic index of 0 per cent. and a sporozoit rate of 0 per cent. That it is difficult to cultivate malaria experimentally in this species.

2. That the distribution of *A. Christophersi* corresponds closely with an area of extremely high endemicity. That the sporozoit rate in this species is as high as is usually found in tropical Africa.

We may point out also that the *species of parasite* should also be taken into consideration. It is manifestly not accurate to compare these with one another as simply so many cases of malaria. It is possible that all three parasites do not develop with equal facility in the different species of Anopheles. The question of "*species*" of Anopheles in relation to malaria requires to be worked out much more carefully than has yet been done.

"Some Points in the Biology of the Species of Anopheles found in Bengal." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received October, 1901. (The Determination of the Species by F. V. THEOBALD, M.A.)

In an accompanying Report (The Relation of Endemicity of Malaria to the Species of Anopheles) we show that the power of transmitting malaria appears not to be possessed in the same degree by all species, and whilst it is even probable that some species may not be concerned at all in the spread of malaria, the presence of other species is associated with a high rate of malarial endemicity.

It is very necessary, then, that the habits of life of each species of Anopheles should be determined, as pointed out by Nuttall, not in general terms but for each particular species.

In the present paper we note such differences as were observed by us in the habits of the species of Anopheles which were found by us in Bengal. These were six in number—*Anopheles Rossii* (Giles), *Anopheles fuliginosus* (Giles), *Anopheles sinensis*, sub-sp. *nigerrimus* (Giles), *Anopheles Lindesayi* (Giles), and two new species. These latter resemble *Anopheles costalis* and *Anopheles funestus*, but specimens sent to Theobald were found by him not to be these species. They are described by Theobald as *Anopheles metaboles* and *A. Christophersi*. It was found possible to distinguish both the eggs and larvæ of these species. The eggs of the species under discussion vary more than the larvæ, and, indeed, could sometimes be distinguished by the unaided eye. The eggs of two species—*A. nigerrimus** and *A. Christophersi*—are characterised by an extremely narrow upper surface (see fig. 3, *c*, *d*). Those of *A. Rossii* are unique in possessing a broad fringe-like structure arising from the borders of the upper surface (see fig. 3, *a*).

The larvæ may be distinguished by an examination of the antennæ, of four small hairs hanging over the mouth, of the number of segments bearing palmate hairs, and of the individual leaflets of the palmate hairs. The presence of a large branched hair arising from the inner border of the antenna occurs in only one of the species—*A. nigerrimus.* The four small hairs over the mouth have been noted by Grassi as presenting differences of specific importance.

In the species under discussion the central pair do not present any marked differences. The outer pair, however, may be simple as in *A. Rossii*, *A. metaboles*, or they may be branched as in *A. nigerrimus*, *A. fuliginosus*, and *A. Christophersi*, so as to form a cocade-like tuft over the feeding brushes.

* *A. nigerrimus* is used for brevity; it should read all through as *A. sinensis*, sub-sp. *nigerrimus*. (F. V. T.)

Fully developed palmate hairs are as a rule confined to the last five abdominal segments. A small imperfectly formed hair is also frequently present on the 2nd abdominal segment. In *A. Christophersi*, however, every abdominal segment bears a fully formed palmate hair, and there is an imperfect pair situated on the posterior portion of the thorax. *A. Lindesayi* also has fully developed palmate hairs on the last six abdominal segments.

A palmate hair consists of from 14 to 20 leaflets, arranged so as to form a structure resembling the leaf of a Palmyra palm. The leaflets, towards their distal extremities, are more or less jagged or notched, and, except in *A. nigerrimus*, are continued past these notches only as a filament considerably narrower than the basal portion of the leaflet. The character of the notching and the length of the terminal filament compared with the basal portion were found by us to be of specific nature (see fig. 1).

The following is a description of the main differences in the eggs and larvæ of the species under discussion :—

A. Rossii (see figs. 1, 2, and 3).

Egg.—Anterior surface very broad.

Frill very wide and continued around the edge of the upper surface so that it passes above the floats.

Floats are of the shape of a scallop-shell and reach the border of the upper surface.

Lower surface of egg without distinct polygonal markings.

Larva.—Antenna without large lateral branched hair.

Hairs over mouth unbranched.

Palmate hairs borne by 3rd, 4th, 5th, 6th, and 7th abdominal segments. Imperfectly formed palmate hair on 2nd abdominal segment.

Palmate hairs rather small. The terminal filament half the length of the whole leaflet.

A. fuliginosus (see fig. 3, *b*).

Egg.—Upper surface rather narrow.

Fringe rudimentary. Fringe is not continued above floats, being wanting in the portion of the edge of the upper surface where the floats are placed.

Floats regularly oval and touch margin of upper surface.

Lower surface of egg not marked by definite polygonal areas.

Larva.—Antenna without large lateral branched hair.

Outer pair of hairs over mouth developed into a tuft.

Palmate hairs borne by 3rd, 4th, 5th, 6th, and 7th segments.

Palmate hairs dark in colour, very markedly jagged. Terminal filament not so long as basal portion.

A. sinensis, sub-sp. *nigerrimus*. (See figs. 1, 2, and 3.)

Egg.—Upper surface very narrow.

Fringe rudimentary. Passes all round margin of upper surface.

Floats oval.

Floats do not reach margin of upper surface, but leave a portion of lower surface of egg intervening.

Lower surface marked by silvery lines into polygonal areas.

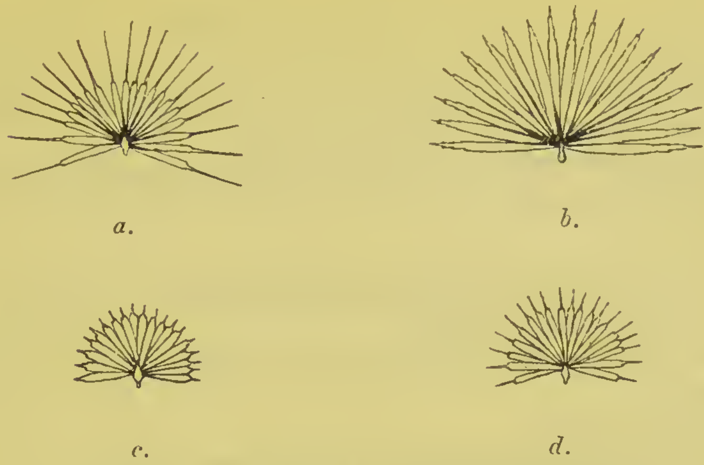


FIG. 1.—Palmate Hairs of Larval Anopheles.

a. A. Rossii; b. A. nigerrimus; c. A. metaboles; d. A. Christophersi.

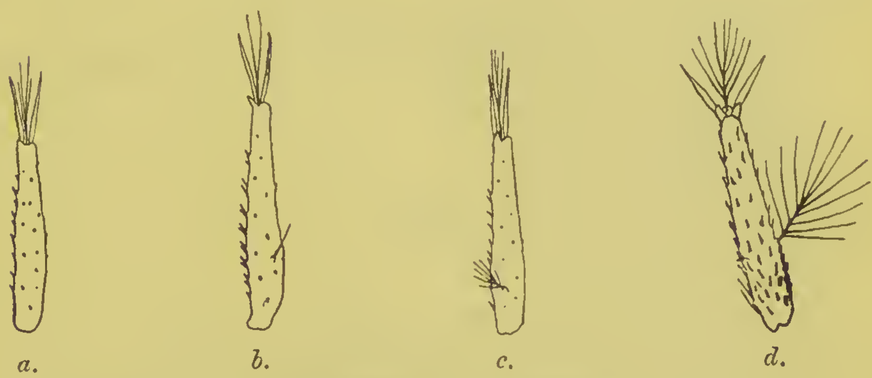


FIG. 2.—Antennæ of Larvæ.

a. A. Rossii; b. A. metaboles; c. A. Lindesayi; d. A. nigerrimus.

FIG. 3.—Ova of Anopheles.

a. A. Rossii; b. A. fuliginosus; c. A. nigerrimus; d. A. Christophersi.

Larva.—Antenna with large branched hair arising from inner border.

Outer pair of hairs over mouth developed into large very prominent cocade-like tufts.

Palmate hairs borne by 3rd, 4th, 5th, and 6th abdominal segments. Imperfect palmate hair on 2nd segment.

Palmate hairs very large. Leaflets lanceolate in shape, with the terminal third deeply serrated.

A. Lindesayi.

Egg.—Not observed.

Larva.—Antenna with small rudimentary branched hair. (Fig. 2, *c.*)

Hairs over mouth unbranched.

Palmate hairs borne by 2nd, 3rd, 4th, 5th, 6th, and 7th abdominal segments.

Palmate hairs large.

Terminal filament long, but not so long as basal portion.

A. metaboles (see figs. 1 and 2, *c* and *b*).

Egg.—Not observed.

Larva.—Antenna with rudimentary hair, unbranched.

Hairs over mouth unbranched.

Palmate hairs borne by 3rd, 4th, 5th, 6th, and 7th abdominal segments. Imperfect hair on 2nd segment.

Palmate hairs rather large.

Terminal filament very short.

A. Christophersi (see figs. 1 and 3, *d*, *d*).

Egg.—Egg smaller than in other species.

Upper surface very narrow.

Fringe rudimentary.

Floats do not touch edge of upper surface.

No polygonal markings on the lower surface of the egg.

Larva.—Antenna without large lateral branched hair.

Outer pair of hairs over mouth developed into small tuft.

Palmate hairs borne by all abdominal segments. Imperfect palmate hair on thorax.

Palmate hairs large. Terminal filament rather short, but longer than that of *A. metaboles.*

The distribution of the Species.—*A. Rossii* was found everywhere by us—from Calcutta to the foot of the Himalayas, and at an elevation of 3000 feet. In the Duars it was comparatively rare. In Calcutta, on the contrary, it was by far the commonest species, and in many parts of Calcutta appeared to be the only species present.

A. Christophersi was only found by us in the Duars district, and it was not found above a height of about 1000 feet.

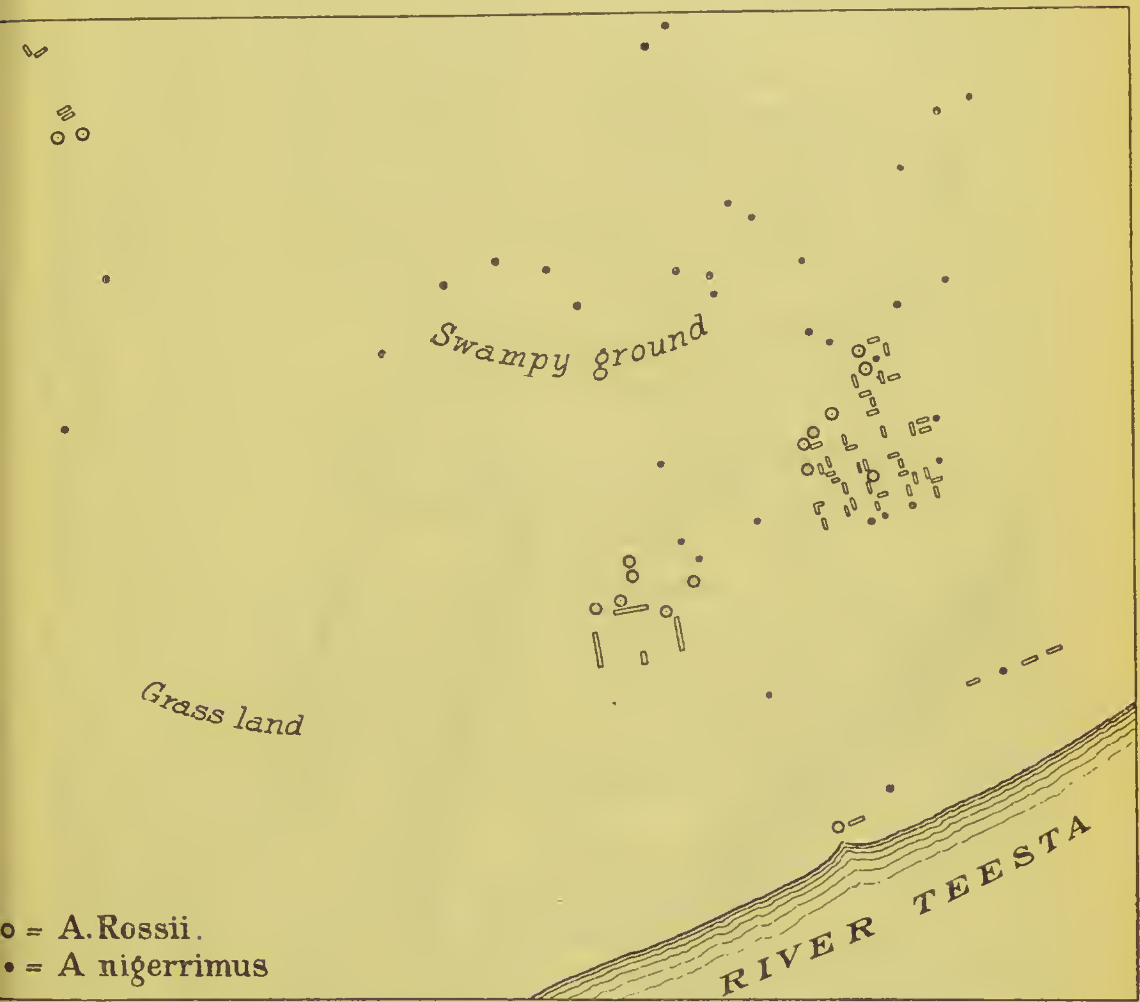
A. metaboles occurred in small numbers as one approached the foot of the hills. It was the commonest Anopheles in the upper portions of the Duars and lower hills. It occurred also at an elevation of nearly 5000 feet near Kurseong.

A. fuliginosus was found scantily in the plains and at a height of 800 feet.

A. nigerrimus was, except in Calcutta, a common species in the plains, and larvæ were found at a height of 1200 feet in the Duars.

Habits of the different Species.

A. Rossii.—*A. Rossii* was found by us always near human dwellings, and often in very foul water. In spite of the commonness of the species, larvæ were never found by us more than a stone's-throw from dwellings. If in any place larvæ were discovered at a greater distance



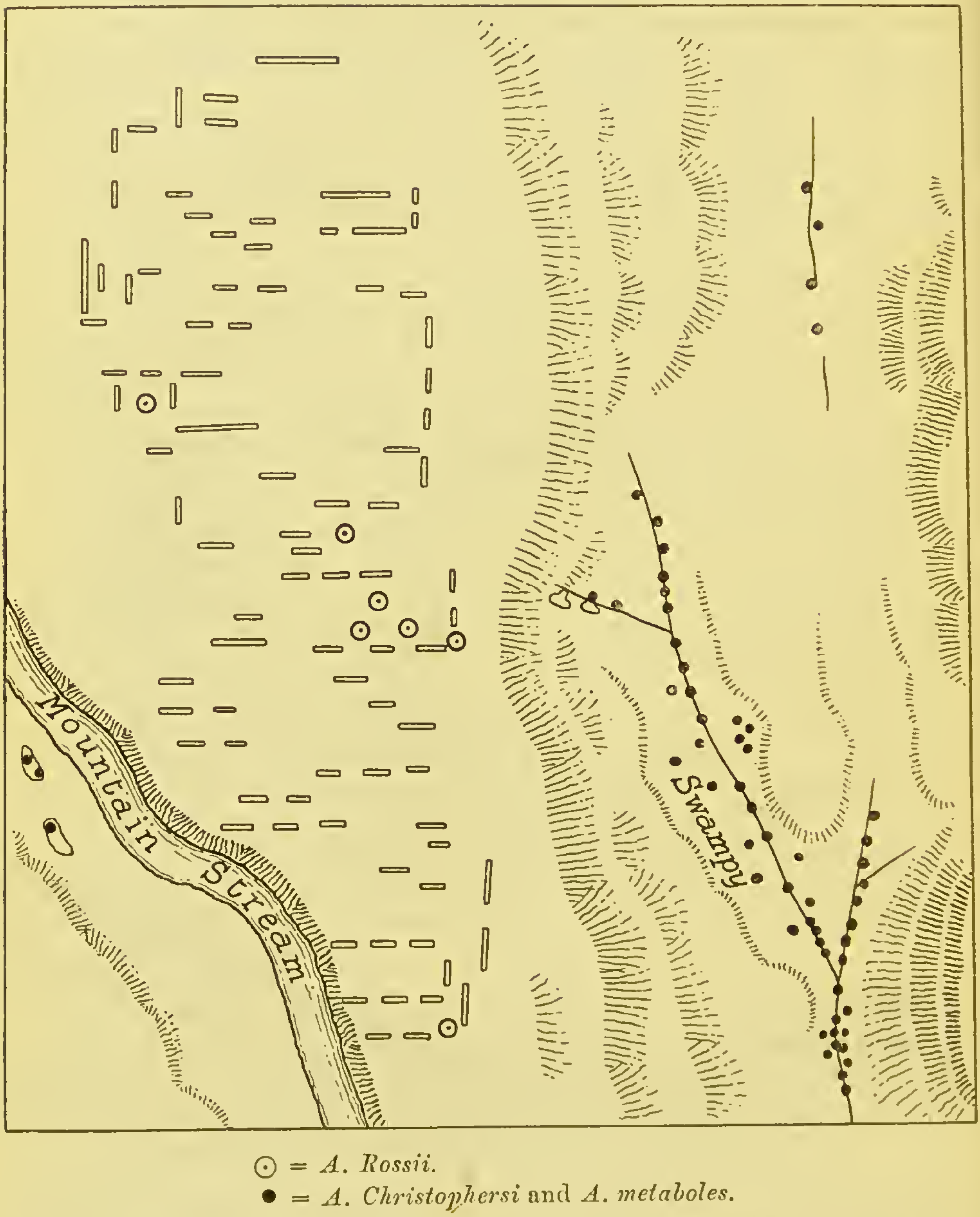
PLAN I.—To show distribution of breeding-places of *A. Rossii* and of *A. nigerrimus*. Open circles = *A. Rossii*; solid circles = *A. nigerrimus*.

they invariably turned out to be larvæ of other species. *A. Rossii* appears, then, in Bengal to be "foveal" in its distribution, in contradistinction to other species of Anopheles to be described.

In Plan I the distribution of *A. Rossii* breeding-places can be compared with those of *A. nigerrimus*, in Plan II with those of *A. metaboles* and *A. Christophersi.*

In captivity *A. Rossii* lays eggs more readily than *A. fuliginosus* or *A. nigerrimus.* The eggs laid on mud were sometimes deposited in a heaped up mass, in others scattered over the surface of the mud. Some of the eggs of *A. Rossii* do not become black, and these appear

to dry up quickly and do not develop. Sometimes the whole of the eggs laid are of this nature, at others a certain number are normal, whilst others remain white or change only to a reddish tinge.



PLAN II.—Portion of Coolie Lines on a Tea Plantation—to show breeding-places of *A. Rossii*, *A. Christophersi*, and *A. metaboles*.
Open circles = *A Rossii*; solid circles = *A. Christophersi* and *A. metaboles.*

The eggs of *A. Rossii* possess very slight powers of resisting desiccation. Gravid females of *A. Rossii* were allowed to deposit eggs upon moist mud in a large earthenware vessel. The mud was then allowed to dry out of doors. From time to time portions of mud were removed and the eggs floated on to the surface of water in such

a way as not to wet them. At the end of 24 hours the surface of the mud was almost dry. Eggs removed and placed in water hatched in a few minutes. At the end of 48 hours the mud was quite dry. Eggs removed and added to water hatched in a few minutes. On the third day eggs removed and added to water did not hatch. On the fourth day the whole mass, with many hundreds of eggs upon its surface, was carefully moistened, but no larvæ hatched out. There does not appear to be, then, any probability of the eggs of *A. Rossii* resisting even a short period of drought in the course of nature.

The larvæ of *A. Rossii* usually occur in very large numbers in the pools they frequent. Other species do not seem to breed in such a crowded state. The food of the larvæ varied somewhat in different situations. In all there was much sand. In larvæ from shallow newly formed rain pools on mud, the gut contents were largely composed of bacilli and small infusoria. In water of a more permanent nature, algæ of several species, and a great variety of unicellular green vegetable cells, were found. Diatoms, though present, rarely formed a large proportion of the food.

The larvæ of *A. Rossii* appear unable to resist drying, even for a few hours. A number allowed to remain on drying mud very quickly died.

Experiments were made to determine how far *A. Rossii* selected a particular kind of water for the deposition of ova. A number of gravid females were placed in a large mosquito net along with earthenware vessels containing different waters. It was found that very little if any choice was shown between pure water, green stagnant water, or even very foul sewage, eggs having been laid in the same night in each of these vessels.

A. Rossii will readily lay eggs on half dry or dry mud, and confined in a dry tube or bottle will lay eggs upon glass.

A few observations were also made on the natural enemies of Anopheles larvæ. While some fish (*e.g.*, a small fish which was identified by Major Alcock, I.M.S., F.R.S., as a young carp, and which occurred abundantly in the larger tanks in Calcutta) feed voraciously on larvæ, others do not eat any.

The following table will give a rough idea of the rate at which the commoner water creatures devour larvæ :—

	Number of larvæ added.	Number after 1 hour.	Number after 12 hours.
Large libellula larva	20	7	1
Small ,, ,, ...	12	7	0
Beetle (Dytiscidæ)	12	9	2
*Beetle (Clavicorn)	9	9	8
Small dytiscid larva	8	4	2
Coryxa	9	3	0
Nepa	16	5	2
*Tadpole (small species)......	9	9	8

From 50–100 larvæ were added to large earthenware vessels containing one or two specimens of the following, which are the commonest tank fish :—

Fish.	Observation.
2 Catfish	Larvæ gradually disappeared during several days.
6 Young barbus	Larvæ all disappeared in 15 minutes.
8 Trichogastra........	Larvæ slowly diminished.
4 Polyocanthus	Very few larvæ eaten.
2 Small carp (adult) ..	Larvæ apparently undiminished at end of 48 hours.
A small acclimatised salt-water fish	Larvæ not eaten.

Twelve specimens of the young barbus were then added to a small cement tank containing numerous larvæ. At the end of 24 hours no larvæ were visible, and the pool remained free for 6 days, the period during which it was under observation.

It is evident that these small fish devoured larvæ far more rapidly than the other fish used, and than any of the insect enemies. This is a common fish, and is easily caught. It is, moreover, a fish not readily killed by foul water or transportation. For tanks and small collections of water, which it is undesirable to do away with, the introduction of a number of these fish would appear to be at least worth a trial. With regard to experiments with *A. Rossii* we can say :—

1. Little or no selection of water is exercised by the female in laying her eggs.
2. The eggs do not stand desiccation for more than 48 hours.
3. The larvæ are still more susceptible to desiccation.
4. Of small water animals, larvæ of libellula, beetles of carnivorous habits and their larvæ, coryxa and nepa all feed upon larvæ.

* The disappearance of a single larva after so many hours was probably accidental, as larvæ of various sizes were used.

5. Some species of fish are much more voracious feeders on larvæ than others.

A. nigerrimus.—While *A. Rossii* is foveal, *A. nigerrimus*, on the other hand, is non-foveal. Though the insects were seldom caught by us in houses, yet it is a common species, and the larvæ, unlike those of *A. Rossii*, are to be found plentifully in sluggish streams, river banks, marshes, and swampy pools.

This species was at first thought by us to be a somewhat rare species, as it seldom occurred in collections of Anopheles made in different quarters. On examining natural waters, however, we found the larvæ to be very prevalent.

Unlike the larvæ of *A. Rossii*, the larvæ of this species occur singly, and can only be detected by frequent "dipping" amidst the grass and water plants. Taking into consideration the great extent of waters that *A. nigerrimus* larvæ were found in, this species is, in the marshy parts of Bengal, one of the commonest.

The larvæ of *A. nigerrimus* were found apart from collections of huts, and though they occurred in deep water, even in the midst of villages, yet they were not more numerous in these situations than elsewhere. It is noteworthy that in one situation, where deep ditches with clean stagnant water were situated side by side with shallow foul puddles, the larvæ of *A. Rossii* were never found in the former but were numerous in the latter, whereas those of *A. nigerrimus* occurred only in the former. Although the adults of this species were only rarely found in houses, yet it readily fed upon human blood. The habits of this species therefore require elucidation.

A. Christophersi.—In the Duars this species breeds in sluggish streams with grassy edges. It was never found by us in puddles in the coolie lines, or in small pools on roads, paths, &c. In some cases larvæ were dipped up from water running with considerable velocity, but always amongst the grass at the edge. The adults were found in the coolie huts, but were difficult of detection from their small size. It is possible that this species has a more powerful flight than *A. Rossii*, as the larvæ usually occurred some distance from the huts. In one case the nearest breeding place was 200 yards away.

A. metaboles.—The larvæ of this species also occur in streams more or less rapid. They are also abundant in swampy tracts by the side of streams, in rice fields, and small pools. They are not found in the small foul pools in the coolie lines. They occur at a height of 5000 feet. This species has been found by us at very considerable distances from habitations.

A. fuliginosus.—In Fort William, Calcutta, the insects were common. Elsewhere we have very seldom caught the adults. The larvæ were found in the same situations as those of *A. nigerrimus*, but they were not so numerous.

A. Lindesayi.—This species was only found by us in the hills at a height of about 4000 feet. It was breeding together with *A. metaboles.*

Summary.

1. *A. Rossii* is a foveal species and will breed in foul water.
2. *A. nigerrimus* occurs quite apart from habitations. It only breeds in marsh water.
3. *A. metaboles* occurs from the base of the hills to 5000 feet. It breeds in pools, swampy edges of streams, and rice fields. It has been found by us at great distances from dwellings.
4. *A. Christophersi* is, in the Duars, almost confined to small streams. It does not extend very high into the hills, and in the part of Bengal seen by us is present only along the base of the hills.

"The Relation between Enlarged Spleen and Parasite Infection." By J. W. W. Stephens, M.D. Cantab., and S. R. Christophers, M.B. Vict. Received October, 1901.

Discussions have recently arisen in scientific literature on the value of the so-called "spleen test" for malaria. Arguments based on this test appear to us not conclusive; because, so far as we know, no data have hitherto appeared in which the spleen rate and parasite rate have been simultaneously determined. While engaged, then, in determining the parasite rate or endemic index of various localities in Bengal, we took the opportunity of determining the spleen rate among the children examined. The data thus simultaneously acquired, and the conclusions to which they lead us, form the subject of this Report.

It is well known that intense malaria may exist without any corresponding affection of the spleen. Thus, F. Plehn,* speaking of enlarged spleen, says: "Sie ist in der überwiegenden Mehrzahl der Fälle nicht grösser als in den von mir in Deutschland beobachteten Fällen von Abdominaltyphus, häufig wesentlich kleiner"; and Daniels† "concludes that as a test for the prevalence of malaria the spleen test may be worse than useless, unless race and age are taken into account." Ross, we believe, found in Freetown, Sierra Leone, very few enlarged spleens amongst the troops suffering from malaria there.

But in India there exists little doubt that amongst natives and Europeans enlarged spleen is one of the commonest occurrences in those suffering, or who have suffered, from malaria. For in the wards

* 'Die Kamerun-Küste,' p. 97.

† 'Thompson-Yates Reports,' 1901.

of the large native hospitals in Calcutta, among the large number of "fever" cases (in July), the great majority were classified as suffering from "malarial cachexia and enlarged spleen." These cases were briefly characterised by anæmia, with an enlargement of the spleen varying from 2—3 fingers' breadth to that of a spleen filling the whole of the left side of the abdomen, and reaching to the pubes; and these cases were quite common. These cases were also not infrequently accompanied by a temperature which oscillated in an irregular way between 99° and 101°, and which might persist for weeks. Quinine or cinchona, as far as we could see, frequently exerted no influence on the course of the temperature.

When we came to examine these cases microscopically, they consistently showed a complete absence of parasites. We examined over 80 of such cases, and in none did we find parasites, or pigmented leucocytes, or any mononuclear leucocyte increase such as we have shown in earlier Reports to be characteristic of a recent infection.

Many of these patients were taking cinchona, but others were not; and in neither were these subsidiary signs of malarial infection—pigment and a mononuclear increase—present.

Further, we had the opportunity of making *post-mortem* examinations on six cases, and in none of these were parasites found in the bone marrow or spleen; though pigment was present in variable amount.

We do not consider these to be new facts, for similar ones have been recorded by Kelsch and Kiener, Ross and Daniels, under the designation "symptomatic fever." We here wish chiefly to point to the importance of these cases from the point of view of classification. It can be of little value to classify cases of this kind (so-called malarial cachexia) with those of, say, simple tertian with numerous parasites in the circulation, under the general heading of malaria (ague or remittent fever). This classification, however, prevails in India; and for this, among other reasons, hospital and dispensary statistics are of little if any value. It can only be by a microscopic differentiation of cases according to the variety of parasite that a true classification can be founded.

In Calcutta, then, we had a series of 80 cases of enlarged spleen without any corresponding parasite infection. No doubt they represented past cases of actual infection with parasites; but, as we shall soon see, they tell us little, though swelling the hospital statistics, of the actual malarial endemicity of Calcutta. In an accompanying Report we have taken the test of the endemicity of malaria, as first shown by Koch, to be the percentage of children (under 10 years of age) infected with parasites. With the endemic index thus obtained we compare, in the following table, the spleen rate :—

Table I.—To show relation between Spleen Rate and Parasite Rate.

Locality.	Spleen rate.	Endemic index.	No. of children examined.
Calcutta	0	0	191
Jalpaiguri—			
Bustee children......	27	16·1	37 and 62
School..............	14·7	0	210 and 80
Babu children	14·2	0	21 and 21
Mainaguri	74	25	51 and 41
Rungamutty...........	83	43·6	72
Sam Sing (2000 ft.)	7·1	16	14
Kurseong I (5000 ft.) ..	0	0	25
Kurseong II (2000 ft.)..	·2	0	20

We see that there is, with some exceptions to be noted, a fair correspondence between enlarged spleen and endemic index from a spleen rate of 0 at Calcutta, with an endemic index of 0, to a spleen rate of 83 at Rungamutty, with an endemic index of 43·6. Further, we see that, with one exception, the spleen rate is higher than the endemic index. The reason of this is, no doubt, that those children who at one age-period have suffered from malaria and enlarged spleen, still have the enlarged spleen at a later age-period, when the actual parasite rate is less.

So in adults we frequently have a number of enlarged spleens without any corresponding parasite infection, as in the case of 19 enlarged spleen cases in Jalpaiguri Jail, none of which showed parasites.

The spleen rate taken without modification is not a true test of the presence of malaria. Moreover, in making comparisons it is necessary that rates for corresponding age-periods should be compared.

An analysis of Table I gives the following results :—

Table II.

	Age.	Spleen rate.	Endemic index.	Number of children.
Jalpaiguri— Bustee children..	1— 5	12·5	0	8 and 17
	6—10	10·5	16·6	19 and 24
	11—15	62·5	18·7	8 and 16
Mainaguri........	1— 5	52·3	37·5	21 and 16
	6—10	85	26·6	20 and 15
	11—15	100	0	10 and 10
Rungamutty	1— 5	77·4	48·3	31
	6—10	81·5	39·4	38

With one exception, then, we see that with increasing age the endemic index decreases (this is constantly the rule as found in West Africa), yet the spleen rate goes on increasing.

A factor beyond those already mentioned may cause a variable spleen rate, namely, the kind of parasite. In India we have found the quartan most commonly in the native children examined by us. It is also generally agreed that the simple tertian causes greater enlargement of the spleen than the malignant tertian.

The following conclusions may, we think, be drawn from these facts :—

1. A high endemic index may exist without any appreciable spleen rate (Africa).
2. A high spleen rate may exist in adults without a corresponding parasite infection.
3. In India (Bengal) among children a high spleen rate is a fair indication of the parasite infection.
4. The spleen rate, unlike the parasite rate, increases up to a certain age limit, and may be considerable when the parasite rate is nil.

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1902.

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Reports from Messrs. STEPHENS and CHRISTOPHERS, India :

REPORTS, &c., FROM MESSRS. STEPHENS AND CHRISTOPHERS, INDIA.

"The Classification of Indian Anopheles into Natural Groups." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received February 6, 1902.

[PLATES 1—4.]

We would take this opportunity of acknowledging our indebtedness in all our Indian work to Captain S. P. James, I.M.S., who was attached to the Malaria Commission by the Indian Government. He has throughout assisted us in the examination of blood films, dissections, and other incidental work. We are especially indebted for much help in the differentiation of the species of Indian anopheles.

Since it seemed possible to us that the question of species of Anopheles might be an important factor in determining variations in the distribution of malaria, we have investigated the appearance of the adult insect, the character of the ovum and larva, and the habits of each species encountered by us in India.

The result of this investigation has been to show that a subdivision of the genus *Anopheles* into several natural groups can be made.

The members of some of these groups very closely resemble one another in almost every particular, especially in the habits of the species.

The Adult Insects.

The species of Anopheles noted in India are at present the following:—

(1) *A. barbirostris* (Van der Wulp).
(2) *A. Sinensis* (Wied.).
  Sub-sp. *nigerrimus* (Theobald).
  Syn. *A. nigerrimus* (Giles).
(3) *A. culicifacies* (Giles).
(4) *A. Listonii* (Giles).
(5) *A. Christophersi* (Theobald).
(6) *A. Indicus* (Theobald).
(7) *A. Jamesii* (Theobald).
(8) *A. fuliginosus* (Giles).
  Syn. *A. Jamesii* (Liston).
(9) *A. maculatus* (Theobald).
(10) *A. Theobaldi* (Giles).
(11) *A. Rossii* (Giles).
(12) *A. Stephensi* (Liston and James).
  Syn. *A. metaboles* (Theobald).
(13) *A. pulcherrimus* (Theobald).
(14) *A. Turkhudi* (Liston).
(15) *A. Lindesayi* (Giles).
(16) *A. Gigas* (Giles).

Many of these species are obviously closely related, and differ from one another only in minute particulars. Considering only the adult female, the species known to us may be grouped as follows:—

Group I. Large black species with broad scales upon many of the veins of the wings.

A. barbirostris.
A. Sinensis, sub-sp. *nigerrimus.*

Group II. More or less dark species with markedly banded legs of white tarsi.

A. maculatus (Theobald).
A. Theobaldi (Giles).
A. Jamesii (Theobald).
A. fuliginosus (Giles).
A. pulcherrimus (Theobald).

Group III. Very small species with dark, unbanded legs; wings with veins, for the most part covered with dark scales.

A. Indicus (Theobald).
A. culicifacies (Giles).
A. Listonii (Giles).
A. Christophersi (Theobald).
A. Turkhudi (Liston).

Group IV. Light brown species with the wings for the most part covered with light scales.

A. Rossii (Giles).
A. metaboles (Theobald).

Group V. *A. Lindesayii* (Giles).

Variations in the Characters of the Adult Insects of each Species.

Many species of anopheles exhibit considerable variation in—

1. The size of the insect. Especially in *A. Rossii* and *A. Stephensi*, but also to a less degree in *A. culicifacies* and other species, we have noted very great differences in the size of individuals.

This we think is due to a lack of nutrition of the larvæ, as larvæ taken from foul and overcrowded puddles most frequently hatch out as small specimens.

2. The wing markings. A degree of variation occurs in the extent of vein covered by each area of dark scales.

In *A. Stephensi* very considerable variations are seen in the first longitudinal vein, so that the second large wing-spot is most variable in form. In this species the wings on the same insect sometimes differ.

In *A. Rossii* an extra dark area is frequently added to the T-spot,* and the first and second costal spots are sometimes confluent.

3. The leg markings may be faint or well marked in the same species.

The Ovum.—The ovum of each species shows marked specific characters.

Three very distinct types of ovum have been seen by us—

Type 1. Ova having the upper surface very narrow, with the lateral floats not touching the margin. (See Plate 1, fig. 1.)

The species with ova of this type are—

A. barbirostris.	*A. culicifacies.*
A. Sinensis, sub-sp. *nigerrimus.*	*A. Christophersi.*

Type 2. Ova having a more or less broad upper surface, with the lateral floats touching the margin. (See Plate 1, figs. 2, 3, and 4.)

Species having ova of this type are—

A. Rossii (Giles).	*A. fuliginosus* (Giles).
A. pulcherrimus (Theobald).	*A. metaboles* (Theobald).

Type 3. Ova with no floats, and with upper surface rudimentary. (See Plate 1, fig. 5.)

One species only has ova of this type, viz.:—

A. Turkhudi (Liston).

Species having ova of the first type have in all cases been species breeding in either open natural waters or running streams.

Species with ova of the second type are in general found breeding in pools.

2. *The Larva.*—The larva of each species also show more or less marked specific differences.

Four groups of larvæ may be distinguished readily by variations in certain hairs, called by us frontal hairs (see 'Report to Malaria Committee,' No. VI).

Type 1. Larvæ with the external pair of frontal hairs converted into a cockade-like tuft. (See Plate 2, figs. 6, 6A, and 6B.)

Species having larvæ of this type are—

A. barbirostris.
A. Sinensis, sub-sp. *nigerrimus.*

Larvæ of this type also have a large branched hair upon the antenna, and the leaflets of the palmate hairs differ markedly from all other larvæ. (See Plate 4, fig. 15A.)

* Especially seen in the male.—(F. V. T.).

Type 2. Larvæ with the external frontal hairs branched, but not developed into tufts. (See Plate 2, figs. 7 and 9.)

A. fuliginosus.
A. pulcherrimus.

Type 3. Larvæ with the external pair of frontal hairs simple and unbranched, and with palmate hairs on every abdominal segment, and on the thorax. (See Plate 2, fig. 10, and Plate 3, fig. 10A.)

A. culicifacies.
A. Listonii.
A. Christophersi.

Type 4. Larvæ with the external pair of frontal hairs simple and unbranched, but with no developed palmate hairs on thorax or first abdominal segment. (See Plate 3, figs. 11, 12.)

A. Rossii.
A. metaboles.

Type 5. Larvæ with two large additional hairs placed behind those already mentioned. Also with first three abdominal segments free from palmate hairs. (See Plate 3, fig. 13.)

A. Turkhudi.

The Habits of the Species.

The habits of the species noted differ in many particulars from one another. This is especially the case in the selection of breeding-places, and the following groups can be distinguished :—

Group I. Open water breeders. Found in water with much aquatic vegetation—ponds, lakes, banks of rivers, swamps.

A. barbirostris.
A. Sinensis, sub-sp. *nigerrimus.*

Group II. Stream breeders. Found in swiftly running streams with grassy edges; also in irrigation ditches and nullahs.

A. culicifacies.
A. Listonii.
A. Christophersi.

Group III. Pool breeders :—

(*a.*) Those selecting clean pools with green alga, especially small pools left in river beds—

A. Jamesii (Liston). *A. Theobaldi.*
A. maculatus. *A. Lindesayi.*

(*b.*) Those found in small muddy pools—

A. Rossii.

A. metaboles (also breeds in pots and tins).

The adult insects of the first group are only occasionally caught in houses. They feed, however, upon human blood.

All other species, except *A. Lindesayi*, have been found by us in houses.

Detailed Description of Species.

A. barbirostris.

Ovum.

Upper surface very narrow.

Floats do not touch margin of upper surface.

Lower surface of ovum ornamented with polygonal markings.

Larva.

Antenna with large branched hair.

External pair of frontal hairs developed into cockades.

Palmate hairs on 2—7 abdominal segments.

Leaflets of palmate hairs lanceolate in shape and deeply serrated in outer half.

Head of larva without pigmented markings.

A. Sinensis, sub-sp. *nigerrimus* (see Report, No. VI).

Ovum.

Upper surface very narrow.

Floats do not touch margin of upper surface.

Lower surface of ovum ornamented with polygonal markings.

Larva.

Antenna with large branched hair.

External pair of frontal hairs developed into cockades.

Palmate hairs (?).

Leaflets of palmate hairs lanceolate with serrations in outer half.

Head of larva without pigmented markings.

The habits of both these species, *A. barbirostris* and *A. Sinensis*, sub-sp. *nigerrimus*, are very similar.

The larvæ are found in water with much aquatic vegetation—rivers, lakes, ponds, and swamps. They are only caught singly, but are generally widespread in their occurrence where large bodies of water are present.

The adults are not usually caught in houses. They seem to be attracted by lights, as on one or two occasions they were caught by us on a sheet illuminated by a lamp.

They are very common in Bengal. *A. barbirostris* was found by us scantily in the Central Provinces, whilst *A. Sinensis*, sub-sp. *nigerrimus*,

occurred in small numbers in the Punjab. Its frequency appears to depend upon the presence or absence of suitable sheets of water.

The female does not readily lay its eggs in captivity.

A. fuliginosus (Giles).

Ovum.

Upper surface moderately broad.

Floats touch margin of upper surface.

Floats long and narrow.

Fringe around upper surface only indicated by white border.

Lower surface not ornamented.

Larva.

Antenna without large branched hair.

External pair of frontal hairs branched (branches usually six in number).

Palmate hairs on 2—7 abdominal segments.*

Leaflets of palmate hairs with very marked "shoulder" at origin of terminal filament. Terminal filament from $\frac{1}{2}$—$\frac{2}{3}$ length of basal portion. (Plate 4, fig. 15B.)

Head of larva with distinctive markings (see Plate 2, fig. 7).

This species was found in very large numbers in villages near Nagpur. It was breeding in considerable numbers, especially in small green pools in the course of a nullah. It was also caught by us in numbers in Calcutta Fort, which is surrounded by a moat. In other places visited by us it has only occurred in very small numbers.

In the Nagpur district it is the commonest species in December.

A. Theobaldi (Giles).

Ovum.

Unexamined.

Larva.

Similar to *A. Jamesii* (Liston) with the exception of the leaflets of the palmate hairs, in which the terminal filament is very short, $\frac{1}{5}$—$\frac{1}{6}$ length of basal portion. (Plate 3, fig. 8, and Plate 4, fig. 16.)

A. maculatus (Theobald) (see Reports to Malaria Committee, No. VI).

A. culicifacies (Giles).

Ovum.

Upper surface very narrow.

Floats do not touch margin of upper surface.

Lower surface not ornamented.

* Rudimentary palmate hairs are frequently present upon other segments than those noted in the descriptions of larvæ. These are, however, so small as not to be mistaken for the functionally active hairs.

A short but distinct fringe is continued around margin of upper surface.

Larva.

Antenna without large branched hair.

Frontal hairs all unbranched.

Palmate hairs on 1—7 abdominal segment, and a pair of fairly developed ones upon the thorax.

Palmate hairs with terminal filament nearly as long as basal portion.

Head with markings (see Plate 2, fig. 10, and Plate 4, fig. 17).

Found in the irrigation ditches in Lahore; also in the running portion of the nullahs near Nagpur. It is the common stream mosquito in these places. The adults are found plentifully in native huts.

A. Christophersi (Theobald).

Ovum.

Upper surface very narrow.

Floats do not touch margin of upper surface.

Lower surface not ornamented.

A small fringe passes around margin of upper surface.

Larva.

Antenna without large branched hair.

Frontal hairs simple.

Palmate hairs on all segments, and very well developed pair on thorax.

The palmate hairs in this species are very large. The terminal filament is nearly as long as basal portion.

Found only in swiftly running streams with grassy edges in the Duars, at the foot of the Himalayas, in Northern Bengal. The common mosquito in the Duars.

A. pulcherrimus (Theobald).

Ovum.

Upper surface broad.

Floats touch margin of upper surface.

Fringe well developed around margin of upper surface. Striations are not present in that portion of the fringe lying over the floats.

Lower surface not ornamented.

Larva.

Antenna without large branched hair.

Outer pair of frontal hairs branched (six branches).

Palmate hairs on 2—7 abdominal segments.

Filament of palmate hair nearly as long as basal portion.

Head markings present.

Found only in Lahore, and sparingly there. Nature of breeding place unknown.

A. metaboles (Theobald).

Ovum.

Upper surface broad, except in central portion where encroached upon by floats.

Floats placed on margin of upper surface so that they touch, or nearly touch, one another in middle line. Floats short and almost globular.

Fringe not well developed.

Lower surface not ornamented.

Larva.

Antenna without large branched hair.

Frontal hairs unbranched.

Palmate hairs on 2—7 abdominal segments.

Leaflet of palmate hair with very short filament, $\frac{1}{5}$—$\frac{1}{6}$ length of basal portion.

Head usually with large black area covering the greater portion (see Plate 3, figs. 12, and Plate 4, fig. 19).

Found in Lahore in pots and tins, in which situation it was the only species present. In Nagpur, breeding in cattle-hoof marks, and other similar small pools by the side of nullah. A rare mosquito in Bengal and Punjab, but very common around Nagpur.

A. Rossii (Giles).

Ovum.

Upper surface broad.

Fringe very well developed and striated throughout whole length.

Floats scallop-shell shape and touch margin of anterior surface.

Lower surface not ornamented.

Larva.

Antenna without large branched hair.

Frontal hairs unbranched.

Palmate hairs 2—7 abdominal segments.

Terminal filament of palmate hair very long; often longer than basal portion. The "shoulder" at the origin of the filament is very slightly marked.

There are markings upon the head (see Plate 3, fig. 11, and Plate 4, fig. 18).

The commonest anopheles in all places visited by us, except Nagpur (in December). Breeds nearly always in small pools near houses. These pools are frequently foul, and nearly always muddy. The female lays her eggs very readily in captivity.

A. Turkhudi (Liston). (Plate 3, fig. 13, and Plate 4, fig. 20.)

A. Turkhudi is a very aberrant type, so far as the ovum and larva are concerned. Both the ovum and larva approach to the characters of the culex ovum and larva. The eggs were laid upon a floating object. When placed upon water they sank. They were laid in the heaped-up manner sometimes adopted by anopheles, especially *A. Rossii* and *A. Jamesii.* The chief characters of the ovum are :—

1. No separation of an upper surface as in all other anopheles ova. At the thicker end of the ovum there is an oval area about a quarter the length of the whole egg. This is glistening white and striated, and probably represents the upper surface of other anopheles ova.

2. There are no floats or any markings representing them.

3. There is a pale area at the thicker end of the egg with a scalloped edge.

4. The ovum is otherwise without markings.

The larva is also culex-like in some of its characters, though undoubtedly much more nearly related to the anopheles type.

The full-grown larva is distinguished by the adoption of the slightly hanging attitude. The chief characters of the larva are :—

1. Two large additional frontal hairs are developed, which reach as far forward as the longest of the hairs, described in other larvæ.

2. The shape of the head varies from that of the ordinary anopheles larva.

3. The palmate hairs are only represented on two or three abdominal segments, namely, the 4th, 5th, and 6th. They are absent on the first three abdominal segments.

4. The palmate hairs are small and poorly developed. The leaflets are irregular and the terminal filament blunt.

This species must be looked upon as a form which in its egg and larval stages has lost many of the characteristics of anopheles eggs and larvæ, and has approached in these stages the characters of the eggs and larvæ of culex.

Nothing yet is known of its habits. It is found in houses, and feeds on human blood.

Taking into consideration all the characters known to us, it is evident that anopheles may be divided into some very natural groups, viz. :—

Group I. Large mosquitoes with black wings. Larvæ with branched hairs on antennæ, frontal tufts, and serrated lanceolate palmate leaflets. Ova of type 1.

The larvæ found in large bodies of water with much vegetation. Adults only occasionally frequenting houses.

The Indian species of this group are :—

A. Sinensis (Wied.).
A. barbirostris (Van der Wulp).

To this group also probably belongs the African species—

A. paludis (Theobald).

Group II. More or less dark mosquitoes. Larvæ with branched frontal hairs, but no branched hairs on antennæ or tufts. Ova of type 2. Larvæ found in clean pools in stream beds and elsewhere. Adults frequenting houses, but presumably also occurring wild.

The Indian species of this group are:—

A. fuliginosus (Giles).
A. Theobaldi (Giles).
A. maculata (Theobald).

Group III. The group of stream-loving anopheles, very small mosquitoes. Larvæ without branched hairs on antennæ and with unbranched frontal hairs, also with palmate hairs on every segment and the thorax.

Larvæ found in streams and ditches. Adults in houses.

The Indian species of this group are:—

A. culicifacies (Giles). *A. Christophersi* (Theobald).
A. Indicus (Theobald). *A. Listonii* (Giles).

To this group belongs the African species—

A. funestus (Giles).

Group IV. A group of domestic species. Light fawn-coloured mosquitoes. Larvæ without branched hairs on antennæ or branched frontal hairs. Also with palmate hairs only on two of abdominal segments. Larvæ found in pools by houses, also in springs, pots, and tins.

The Indian species are:—

A. Rossii (Giles).
A. metaboles (Theobald).

Group V. A very aberrant group containing at present only one species—

A. Turkhudi (Liston).

Group VI. *A. Lindesayi* is apparently entirely a hill species, and does not seem to be related to any other Indian anopheles. In the possession of a fairly well-developed branched hair on the antenna; it approaches the *A. Sinensis* group.

Appendix to paper on "The Classification of Indian Anopheles."
By J. W. W. Stephens and S. R. Christophers.

To the above we are able to add descriptions of the ova and larvæ of *A. Theobaldi* (Giles) and *A. Jamesii* (Theobald).

A. Theobaldi (Giles).

Ovum.—As the females of this species have only been very occasionally caught by us in houses, we have not been able to describe the ovum as deposited by the insect. Fully developed ova removed from a bred specimen showed, however, that the ovum resembled that of *A. Jamesii.* The floats were rather short and situated far forwards as in *A. Stephensi.* The fringe is fairly developed, but does not pass over the floats.

Larva.—Antenna without large branched lateral hair.
Frontal hairs unbranched. (Plate 3, fig. 8.)
Palmate hairs on 2—7 segments
Leaflets of palmate hairs have very short filaments. There are marked notches at the ending of the leaflet in the filament. (Plate 4, fig. 21.)

The larvæ of this species frequent especially sluggish streams with much growth of alga. They were found by us in Nagpur in association with *A. fuliginosus*, *A. barbirostris*, and *A. Listonii.*

The adults are only rarely caught in houses in our experience in Nagpur. The species is a very good carrier of the malignant tertian parasite when artificially fed.

A. Jamesii (Theobald).

Ovum.—(Plate 1, fig. 6).
The upper surface is rather narrow.
The floats are rather short and oval, and are placed far forwards as in the ovum of *A. Stephensi* though less markedly so.
The fringe is fairly developed, but is not continued over the floats.

Larva.—Antenna without large branched lateral hair.
Frontal hairs are peculiar and show a condition intermediate between the branched hairs of *A. barbirostris*, *A. fuliginosus*, and the unbranched hairs of *A. Rossii* and other species. (Plate 3, fig. 14, Plate 4, fig. 15.)
Palmate hairs on 2—7 segments.
Leaflets of palmate hairs have very short filaments. The notching at the termination of the leaflet is not so marked as in *A. Theobaldi.* (Plate 4, fig. 22.)

The larvæ of *A. Jamesii* (Theobald) have only been found by us in one situation, namely, a chain of small muddy puddles connected by trickling water.

The adults occurred in huts close at hand.

A. fuliginosus occurred in thousands in the same huts, breeding freely in a weedy lake. The larvæ of *A. Jamesii* (Theobald), however, could not be detected in the lake.

The three species *A. fuliginosus* (Giles), *A. Jamesii* (Theobald), *A. Theobaldi* (Giles) are in the adult condition very similar. Liston* states that many forms intermediate between *A. Theobaldi* and *A. fuliginosus* occur and thinks these two forms may be but variations of one species. The fact that the frontal hairs of *A. Theobaldi* are simple, while those of *A. fuliginosus* are markedly branched, shows that this is not the case.

The differences between abult specimens of *A. fuliginosus* (Giles) and *A. Jamesii* (Theobald) are indeed so slight that one might consider them very closely related. The characters of the ovum and larva show, however, that *A. Jamesii* (Theobald) is more closely related to the group to which *A. Theobaldi* (Giles) belongs than to that of *A. fuliginosus*.

A group in which the larvæ are characterised by very short filaments of the palmate hairs would contain the following species—

A. metaboles (Theobald).	*A. Theobaldi* (Giles).
A. maculatus (Theobald).	*A. Jamesii* (Theobald).

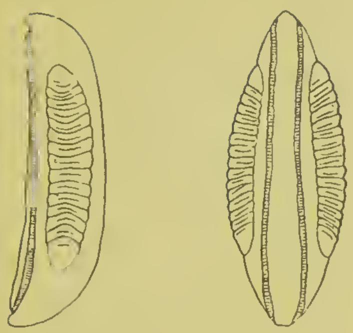
It is also a characteristic of all these species that they have "speckled" legs.

With regard to the large branched hair on the antenna of *A. barbirostris* (Van de Wulp), and *A. nigerrimus* (Giles), we have noticed that a similar structure is very largely developed in some of the culicidæ larvæ. We have been able to separate two forms of larvæ in this group—that of *A. barbirostris*, which is distinguished by the external frontal hairs being closely tufted so as to resemble a shaving brush, and another form which we believe to be the larva of *A. nigerrimus*, in which the external frontal hairs are loosely branched (see Plate 2, fig. 6A). We have, however, not yet succeeded in hatching out adults from this latter form of larva.

J. W. W. Stephens.
S. R. Christophers.

* Communication read at the Malaria Convention at Nagpur, Dec. 1901.

Plate 1.



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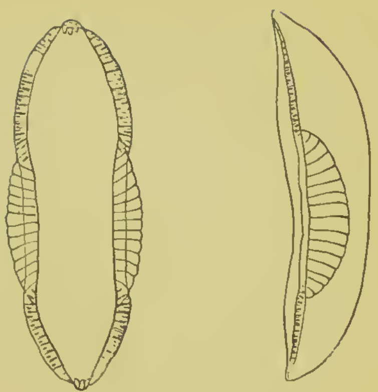

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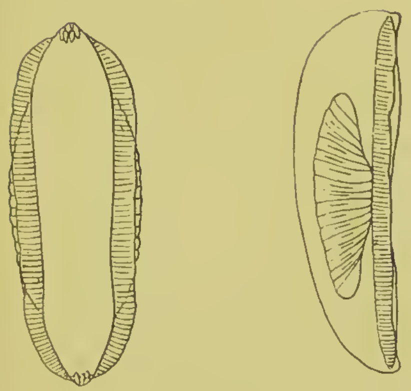

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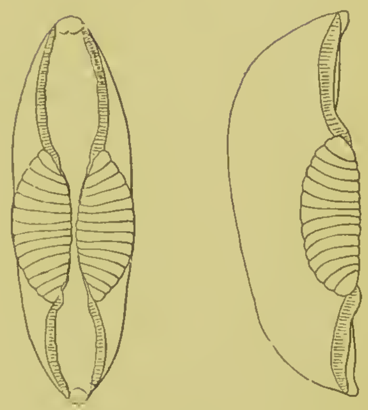

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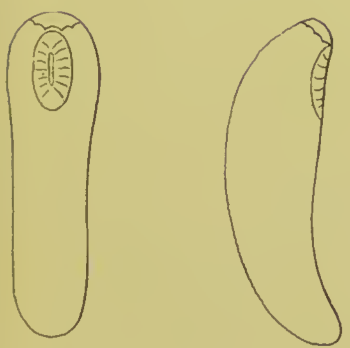

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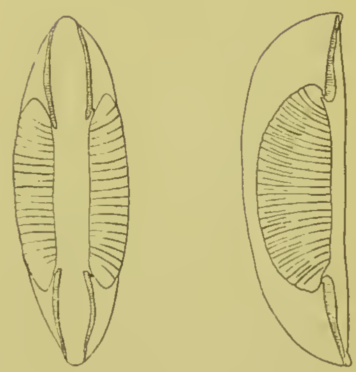
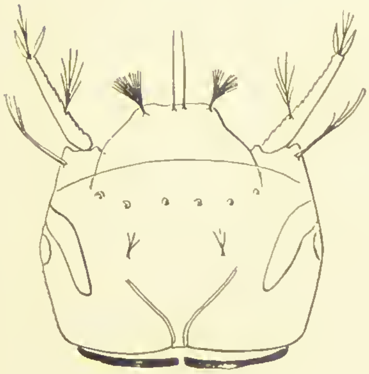


6.

1. *A. culicifacies.* 2. *A. pulcherrimus.* 3. *A. Rossii.*
4. *A. Stephensi.* 5. *A. Turkhudi.* 6. *A. Jamesii.*

Pl. 2, 6A.

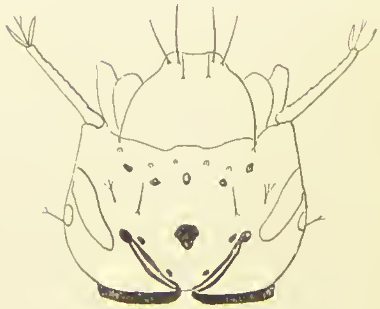
Pl. 2, 6B.



Pl. 2, fig. 6.

Pl. 2, fig. 7.

Pl. 2, fig. 9.



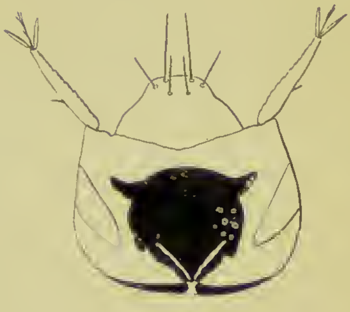
Pl. 2, fig. 10.

6. *A. barbirostris.* 6A. *A. Sinensis*, sub-sp. *nigerrimus.* 6B. *A. barbirostris.*
7. *A. fuliginosus.* 9. *A. pulcherrimus.* 10. *A. culicifacies.*

Pl. 3, fig. 8.

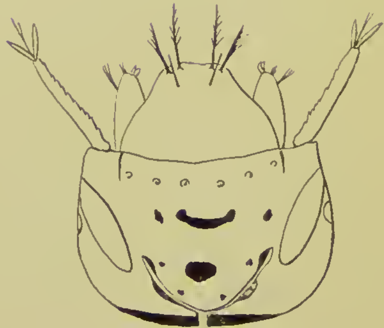
Pl. 3, fig. 10A.

Pl. 3, fig. 11.



Pl. 3, fig. 12.

Pl. 3. fig. 13.



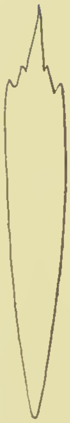
Pl. 3, fig. 14.

8. *A. Theobaldi* (Giles). 10A. *A. Listonii.* 11. *A. Rossii.*
12. *A. Stephensi.* 13. *A. Turkhudi.* 14. *A. Jamesii* (Theobald).

Pl. 4, fig. 15.

15A.

15B.



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17.

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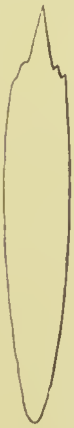

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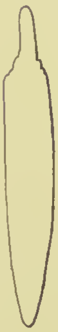


20.

21.

22.

23.

15. *A. Jamesii* (Theobald).
15A. *A. barbirostris.*
15B. *A. fuliginosus.*
16. *A. Theobaldi.*
17. *A. culicifacies.*
18. *A. Rossii.*
19. *A. Stephensi.*
20. *A. Turkhudi.*
21. *A. Theobaldi* (Giles).
22. *A. Jamesii* (Theobald).
23. *A. Listonii.*

"The Relation of Species of Anopheles to Malarial Endemicity."
By J. W. W. STEPHENS, M.D., Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received February 6, 1902.

In a previous report we have shown that some marked variations in the malarial endemicity of Bengal encountered by us were possibly to be explained by a difference in the prevalent species of anopheles.

The conditions encountered there by us were briefly as follows:—

1. In parts of Calcutta *A. Rossii* existed in myriads in the native houses, but, notwithstanding this, there was no malarial infection of the native children nor sporozoits in the anopheles.

2. In the districts around Calcutta, and in several districts in Northern Bengal, *A. Rossii* was the common anopheles, though *A. Jamesii* and *A. Nigerrimus* were also generally to be found. The endemic index in many of these places was 0 per cent., in others it was higher, reaching in one case 16 per cent.

3. From the Mainaguri district, through the Bengal Duars, the endemic index was extraordinarily high, varying from 40 per cent. to 75 per cent. Throughout this district a small anopheles (*A. Christophersi*), resembling the African species *A. funestus*, was common, and in this we readily found sporozoits.

To elucidate this relationship of species to endemicity, there remained two methods at our disposal.

The first was the comparison of the infection of *A. Rossii* and a species that carried sporozoits under identical natural conditions.

The second was the experimental one of feeding on suitable cases at the same time *A. Rossii* and a known carrier.

We have confined our attention chiefly to *A. Rossii*, yet the same problem arises in connection with other species, and a comparison of the relative infection of different species under the same conditions requires investigation.

In Mian Mir (Punjab) we have lately had an opportunity of carrying out the first method of investigation.

Two species of anopheles were common in most of the bazaars, *A. Rossii* and *A. culicifacies*, a small anopheles belonging to the *A. funestus* group (see paper on "The Classification of Indian Anopheles"), and resembling closely *A. Christophersi*. *A. pulcherrimus*, *A. Stephensi*, and *A. Jamesii* occurred in such small numbers in Mian Mir that neither of these could well be the active agent in the transmission of malaria.

In the different bazaars of Mian Mir, infection in the children varied from 20 to 52 per cent.

A bazaar was chosen in which both *A. Rossii* and *A. culicifacies* were readily caught. An examination of the children showed that the spleen rate was 80 per cent. and the parasite rate 52 per cent.

We therefore knew that malaria was being carried by one or both of the species of anopheles.

Specimens of *A. Rossii* and *A. culicifacies* were caught at the same time in the same houses, three in number, in the midst of the bazaar.

In every situation a certain proportion of *A. culicifacies* carried sporozoits, whilst *A. Rossii* was uniformly negative.

The results of our dissections for sporozoits, extending over a month at the height of the fever season (October), were—

	Number dissected.	Number with sporozoits.*	Percentage with sporozoits.
A. Rossii	464	0	Per cent. 0
A. culicifacies	252	11	4·3

so that at the height of the fever season *A. culicifacies* was the chief if not the only species concerned in the transmission of malaria.

It still remained to be seen whether these results would be confirmed by the experimental method. We were unable to continue our work in the Punjab on account of the onset of the cold season. Our feeding experiments were therefore undertaken in Nagpur, in the Central Provinces. Both anopheles caught in the villages† and those bred from larvæ were fed on cases of malignant tertian, simple tertian, and quartan infections. Two cases of malignant tertian were used, both having numerous flagellating forms.

A single case only of simple tertian was available, and this was not a severe infection. Flagellating bodies were, however, seen from time to time.

A case of quartan was also available. This case had a considerable infection of asexual forms, but sexual forms were only occasionally observed.

The results of the experiments were as follows :—

A. Rossii were unfortunately very rare, so that large numbers could not be used.

Mosquitoes caught in village.†
Fed since 10.12.01 on malignant tertian case.
Dissected 15.12.01.

* In these dissections we did not examine the stomachs, wishing, in the first place, to determine merely the sporozoit rate in each species. In every case where sporozoits were found, films were made, fixed, and stained, but no differences in appearance or measurements were to be determined which could enable us to determine whether they were simple or malignant tertian or quartan.

† Results got with these were always confirmed with larval-bred anopheles.

A. Jamesii, a few young zygotes.
A. Jamesii, 3 young zygotes.
A. Jamesii, 3 young zygotes.
A. Stephensi,* a single young zygote.
A. Stephensi, many young zygotes.
A. culicifacies, swarming with young zygotes.

Dissected 22.12.01.

A. Stephensi, swarming with medium-sized zygotes.
A. Rossii, a single medium-sized zygote.

Mosquitoes bred from larvæ.
Fed since 15.12.01 on malignant tertian case.
Dissected 23.12.01.

A. Stephensi, many rather small zygotes.
A. culicifacies, many young zygotes.
A. culicifacies, many rather young zygotes.
A. culicifacies, numerous rather young zygotes. Over 50 seen.

Dissected 25.12.01.

A. Stephensi, many medium-sized zygotes.
A. Jamesii, several young and one medium-sized zygote.
A. culicifacies, large number of medium-sized zygotes. 31 seen.
A. culicifacies, large number of small forms; also many medium-sized forms.

Mosquitoes bred from larvæ.
Fed since 19.12.01 on malignant tertian case.
Dissected 26.12.01.

A. Rossii, neg.
A. Turkhudi, 6 medium-sized zygotes.

Mosquitoes caught in village.
Fed since 18.12.01 on malignant tertian case.
Dissected 26.12.01.

A. Stephensi, 4 small zygotes, 12 medium-sized zygotes.
A. Jamesii, extremely numerous zygotes, 66 medium, 10 small.
A. culicifacies, 4 rather large zygotes.

Mosquitoes bred from larvæ.
Fed since 19.12.01. on malignant tertian case.
Dissected 27.12.01.

* *A. Stephensi* (Liston). Syn. *A. metaboles* (Theobald).

A. Turkhudi, a few medium-sized sygotes.
A. Turkhudi, a small zygote.
A. Stephensi, large numbers of zygotes, 10 or more in some fields.

Mosquitoes caught in village.
Fed since 14.12.01 on malignant tertian case.
Dissected 28.12.01.

A. Stephensi, 24 small zygotes, 266 medium-sized, 42 large zygotes.
A. Rossii, a few young zygotes.

Mosquitoes bred from larvæ.
Fed since 22.12.01 on malignant tertian case.
Dissected 28.12.01.

A. Rossii, 1 small, 6 medium-sized zygotes.
A. Rossii, 7 small, 9 medium-sized zygotes.
A. Rossii, 1 small zygote. Blood not entirely left stomach.
A. Rossii, 12 small, 22 medium-sized zygotes.

Mosquitoes caught in village.
Fed since 21.12.01 on malignant tertian case.
Dissected 30.12.01.

A. Stephensi, 1 medium-sized, 12 large zygotes.
A. Stephensi, over 50 large forms.
A. Jamesii, 7 small forms.

Mosquitoes bred from larvæ.
Fed since 25.12.01 on malignant tertian case.
Dissected 6.1.02.

A. barbirostris, negative.
A. barbirostris, negative.
A. Stephensi, very numerous, nearly fully developed zygotes.

Mosquitoes bred from larvæ.
Fed from 15.12.01 on malignant tertian case.
Dissected 18.12.01.

A. Theobaldi, many young zygotes.

Mosquitoes bred from larvæ.
Fed for 6 days on simple tertian case.

A. culicifacies, a few medium-sized zygotes with simple tertian pigment.
A. culicifacies, negative.

As a result of these experiments, we can say that so far as the development of zygotes is concerned, the following species of anopheles are carriers of the malignant tertian parasite :—

A. culicifacies.	*A. Theobaldi.*
A. Stephensi.	*A. Rossii.*
A. Jamesii.	*A. Turkhudi.*

The only species which has seemed not to carry zygotes is—

A. barbirostris.

As only two specimens, however, have been fed, this result may not be confirmed by further experiments.

Although each of the above species is capable of carrying the zygotes of malignant tertian, yet some difference in the numbers of zygotes found was noted. With one exception in the above experiments, *A. Jamesii* showed only a small number of zygotes, although *A. Stephensi* and *A. culicifacies* in the same batch frequently showed very large numbers.

A. Rossii and *A. Turkhudi*, both undoubtedly carry zygotes. *A. culicifacies* and *A. Stephensi* have always in our experiments shown, however, larger numbers.

Our experiments with simple tertian cases were generally negative. The zygotes of this parasite were, however, seen in *A. culicifacies.*

Experiments with the quartan case have so far been entirely negative.

Further experiments both by dissection of anopheles under natural conditions and by experimental infection are necessary before we can estimate the part played by species in the distribution of malaria. The distribution of quartan and tertian parasites we have shown is peculiar in India. Thus in the Bengal Duars the parasite was almost exclusively quartan, whilst in Mian Mir (Punjab) quartans were not found by us, by far the commonest parasite being simple tertian. What part species may play in this peculiar distribution is not yet evident.

[We are much indebted to Major Buchanan, I.M.S., for the facilities afforded us in the Central Jail, Nagpur.]

"The Relation of Species of Anopheles to Malarial Endemicity.—Further Report." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received April 25, 1902.

In two previous reports we have considered this question. In the first we were led to suggest that species was a determining factor in endemicity from our observations in Bengal.

We found that in the outskirts of Calcutta there were innumerable anopheles, yet the endemic index was nil. The species found in Calcutta was in the main *A. Rossii. A. fuliginosus*, *A. sinensis*, sub. sp. *nigerrimus*, and *A. Stephensi* also occurred.

At Ranaghat, 50 miles from Calcutta, the infection was 14 per cent. At Jalpaiguri, still in the plains, the infection was 16 per cent. At Mainaguri, also in the plains, but on the borders of the Duars, the infection was 25 per cent.

In the Duars, *i.e.*, at the foot of the Himalayas at an elevation of about 800 feet, there was a sudden marked rise in the endemic index, reaching at Nagrakata 72 per cent.

The fact that in the Duars a new anopheles fauna was encountered, the common mosquito being *A. Christophersi*, led us to think that this factor might possibly be the determining cause of the high endemic index.

A. Christophersi is evidently closely allied to the African species *A. funestus*, and as we found later belongs to a group, members of which we have met in another district with an equally high or even higher endemic index.

We showed that dissections of two species, *A. Rossii* and *A. culicifacies*, caught under the same conditions from the same houses gave a very different result. To this point we shall return later in this report.

We showed that in spite of these results, every species but *A. barbirostris* carried malignant tertian when fed experimentally on suitable cases. Since then we have found well-developed zygotes in *A. barbirostris* fed on malignant tertian. We found also that the benign tertian parasite also developed in many species of anopheles.

There was, however, noticeable a difference in the number of zygotes which usually developed in certain species, and the number in certain other species fed at the same time on the same case.

The species which appeared to be most active were :—

A. culicifacies, *A. Stephensi*, *A. Theobaldi*.

Those which seemed less susceptible were :—

A. Rossii, *A. barbirostris*, *A. fuliginosus*.

Lately we have fed anopheles on quartan cases. We may note incidentally, that in other series of feeding experiments we have not found it necessary that the anopheles should be fertilised. Unfertilised anopheles were found by us to convey parasites readily, at least as far as the stage of large zygotes.

The anopheles bred from larvæ were fed every night in rotation on four cases of regular quartan. Four different cases were used, because in only one case on one occasion could a flagellating body be found. The conditions were thus presumably unfavourable, and the four cases were used in the hope of producing infection of the mosquito.

Table I.—Results of feeding Various Species of Anopheles on Quartan Cases.

Date of feeding.	Species of anopheles.	Dissection of stomach.	Dissection of glands.
17th—28th	*A. fuliginosus*	Nil	Nil.
Ditto	Ditto	Nil	Nil.
Ditto	Ditto	Two small zygotes	Nil.
13th—28th	*A. culicifacies*	—	Sporozoits scanty.
Ditto	Ditto	Large zygote	Ditto.
Ditto	Ditto	Nil	Nil.
Ditto	Ditto	Nil	Nil.
Ditto	*A. Theobaldi*	Nil	—
Ditto	Ditto	Nil	Nil.
Ditto	*A. culicifacies*	Small zygote	Nil.
Ditto	*A. Theobaldi*	Nil	Nil.
Ditto	Ditto	Small zygote	Nil.
17th—28th	*A. fuliginosus*	Nil	Nil.
Ditto	Ditto	Large zygote	Nil.
Ditto	Ditto	Nil	Nil.
16th—28th	*A. Rossii*	Small zygote	Nil.
Ditto	*A. culicifacies*	Large zygote	Nil.
Ditto	*A. Rossii*	—	Nil.
Ditto	*A. Stephensi*	Two small zygotes	Nil.
Ditto	*A. Rossii*	Small zygote	Nil.
Ditto	*A. Stephensi*	Nil	Nil.
Ditto	Ditto	Nil	Nil.
Ditto	Ditto	Nil	Nil.

The results (Table I) show that zygotes have developed in four species besides *A. culicifacies*, while in the latter only have sporozoits developed. We would not lay too much stress on this point, as the conditions were unfavourable, but we would point out that *A. culici-*

facies carries quartan sporozoits in nature, while *A. Rossii*, as we shall see later, does not.

Finally we have been able to again find a village of high endemicity where a comparative dissection of the two species occurring in the huts together was possible. Ennur,* a fishing village, 10 miles from Madras, is intensely malarious. We found on examination that the spleen rate was 95 per cent., and the endemic index 54. At first sight it appeared as if *A. Rossii* was the only species present in the huts, for they swarmed in the dirty thatch. Careful search, however, detected also *A. culicifacies*, but while after nearly a week's search only 69 *A. culicifacies* were collected, *A. Rossii* could be caught in hundreds. Here an observer with insufficient experience might reasonably have attributed the high endemic rate of Ennur to the abundance of *A. Rossii*. Dissection here, as in Mian Mir, has conclusively proved that under identical conditions *A. Rossii* is not carrying malaria while *A. culicifacies* is.

It may be noted that in Ennur the infection was almost exclusively quartan, while in Mian Mir it was benign tertian.

The results of our dissections in Mian Mir and Ennur are as follows :—

1. Mian Mir.

	Anopheles dissected.	Number with sporozoits.	Percentage, sporozoits.
A. culicifacies	259	12	4·6 per cent.
A. Rossii	496	0	0 ,,

2. Ennur.

	Anopheles dissected.	Number with sporozoits.	Percentage, sporozoits.
A. culicifacies	69	6	8·6 per cent.
A. Rossii	364	0	0 ,,

We consider then that in spite of the results of feeding experiments *A. Rossii* does not in nature generally carry sporozoits, and is negligible as a carrier of malaria.

A possible explanation is that *A. Rossii* does not live a sufficient time to allow of the formation of sporozoits. Our observations, however, do not favour the view that *A. Rossii* is a short-lived mosquito. The explanation of the difference between this species and *A. culicifacies* is obscure. We may mention that in Ennur zygotes were found in the stomach of one of a small number (18) of *A. Rossii* dissected (observation of Captain S. P. James, I.M.S.).

We have already alluded in previous reports to the general reasons

* We are much indebted to Captain James, I.M.S., for bringing this village to our notice.

which have led us to suppose that other species are also not actively concerned in the transmission of malaria. Thus, for instance, *A. fuliginosus A. sinensis*, and *A. barbirostris* do not seem to be associated with a high rate of infection. The group of small dark mosquitoes with unbanded legs, *A. Christophersi*, *A. Jeyporensis*, *A. Listonii*, *A. culicifacies*, *A. indica*, appear to be eminently the carriers of malaria, and are associated with areas of high endemic index. Two of these, *A. culicifacies* and *A. Christophersi*, have been shown by us to be actively concerned in the spread of malaria in India.

Further observations on the sporozoit rate of associated species are needed in this connection, also for more accurate and detailed knowledge of the distribution of the different species of anopheles and malaria. Whether virulence of infection may depend on such a factor is at present only a matter of conjecture.

"An Investigation into the Factors which determine Malarial Endemicity." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received April 25, 1902.

Information concerning endemic malaria in different countries in the world is meagre. Statements that certain countries are highly malarious while others are comparatively free from malaria, do not allow of accurate comparison between the two. It is only since Koch used the percentage of infected children to obtain a definite figure relative to the prevalence of malaria, that it became possible to compare accurately the endemicity of one district with another. Thus Koch showed that the endemicity of villages in the Dutch East Indies varied from 0 per cent. to 100 per cent.

We have shown that in Sierra Leone, the Gold Coast, and in Lagos a high rate prevails, most frequently approaching 100 per cent. Annett and Dutton also found a similar but somewhat lower rate in most villages in Nigeria. Ziemann, in the Cameroons, also finds a high endemic rate among the children.

Cropper recently,* judging by the spleen rate, shows that areas of high endemicity occur in certain districts in Palestine. He also notes the occurrence of blackwater fever in these districts.

In India we have found areas of high and others of extremely low endemic index. Thus, in the swampy plains of Bengal, over hundreds of miles in extent, the endemic index was uniformly low. Within 30 miles this rate increased until an area, the Bengal Duars and Darjeeling

* 'Journal of Hygiene,' vol. 2, No. 1, p. 47.

Terai, extending for some hundreds of miles, and having an endemic index uniformly high (40—70), was entered.

A similar area of high endemicity has recently been investigated by us in the hill districts of the Jeypore Agency, Madras, where also a striking contrast occurred between the high endemic index of the hill regions and the low index of the adjacent plain districts. It may be mentioned incidentally that in both these regions of intense malaria, blackwater fever is a well-known disease.

With a view to the possible elucidation of such diversities in endemicity as these observations had revealed to us, we determined to examine systematically the causes which influence endemic malaria.

For this purpose we have found that small native villages afford suitable opportunities for observation. The conditions can be determined with some degree of accuracy, and it is possible to select villages where extreme dissimilarities in regard to local conditions are present.

While bearing in mind the possible influence on endemicity of unknown epidemiological factors, we endeavoured in the first place to estimate how far known factors, especially the presence of anopheles, or the extent and proximity of breeding grounds, would account for variations in the parasite rate.

The presence of Breeding Grounds.

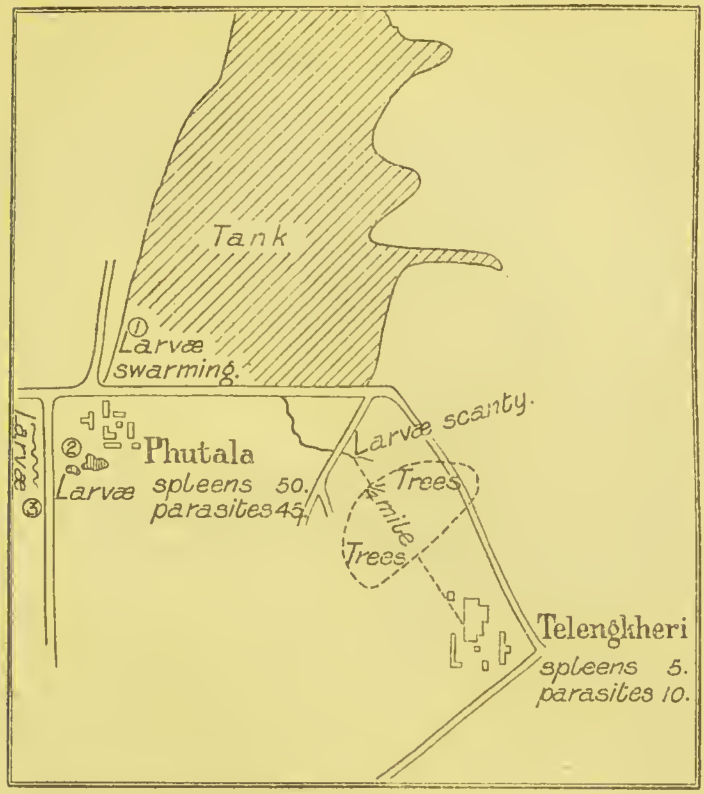
(*a.*) *Extent of Breeding Ground.*—In many villages, especially those where wet irrigation exists, the facilities for breeding are practically unlimited. In other cases a half-dried river bed affords abundance of pools with much weedy growth. On the other hand, the breeding grounds may be scanty and insignificant.

(*b.*) *Distance of Breeding Grounds.*—In swampy districts the village is usually situated in the midst of much shallow water, and breeding places are often within a few yards of the houses. In other villages the breeding grounds are often 200 or 400 yards away. Villages may occasionally be found in which breeding places are not present within as much as half or even one mile.

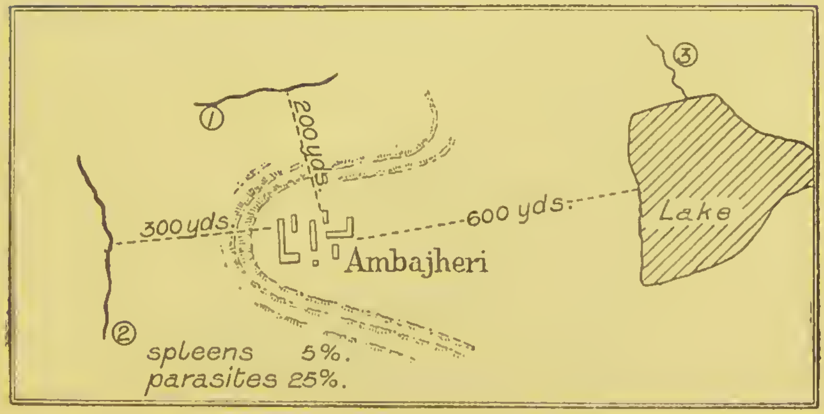
The influence of breeding grounds is shown very clearly in the observations made by us in Nagpur, Central Provinces. Here over a great extent of country, for a considerable part of the year, the breeding places are closely confined to small half-dried-up watercourses.

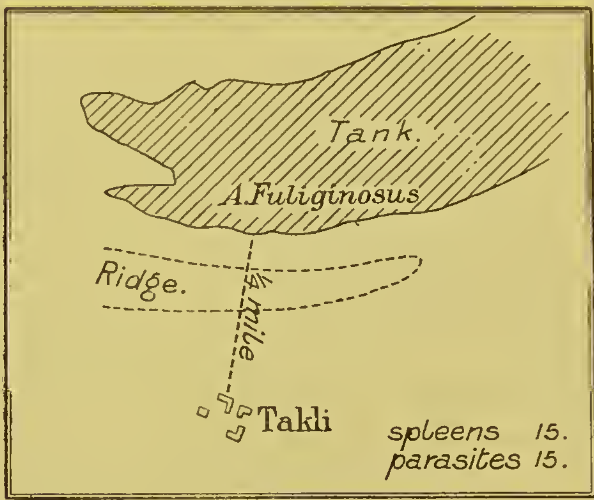
The contrast between "dry" villages with breeding places not nearer than half a mile, and "wet" villages where there were breeding places immediately at hand, is in this district a marked one.

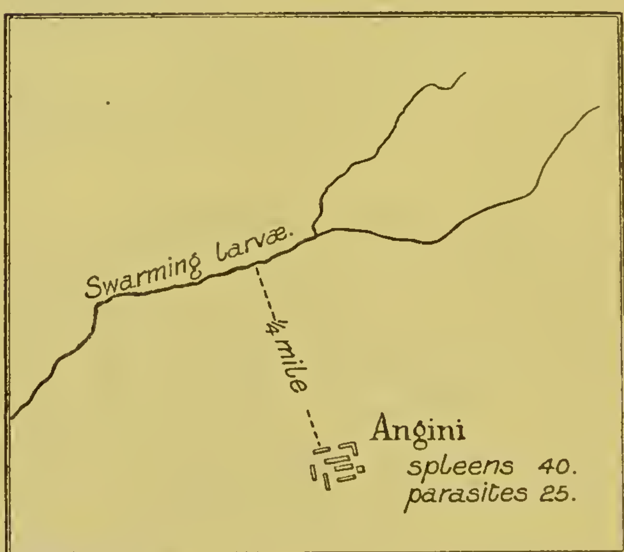
The accompanying plans show accurately the distances of the nearest water, a point which could always be accurately determined, owing to the physical character of the country.

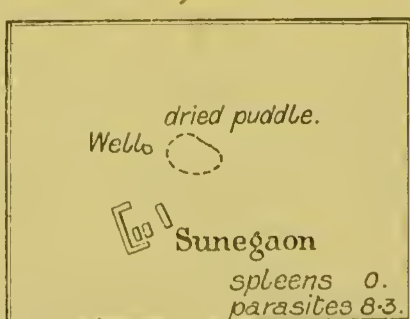

Tank
① Larvæ swarming.
Larvæ ③
② Larvæ
Phutala
spleens 50.
parasites 45.
Larvæ scanty.
Trees
mile
Trees
Telengkheri
spleens 5.
parasites 10.

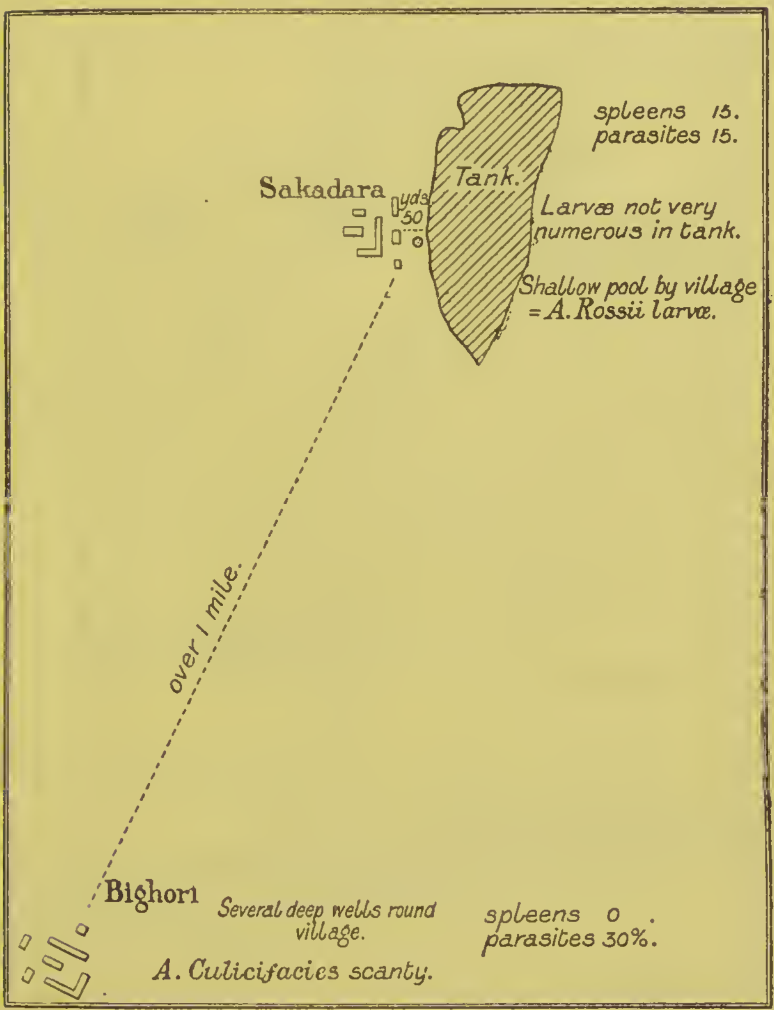

200 yds.
Larvæ
Digdoh
spleens 20.
parasites 25.

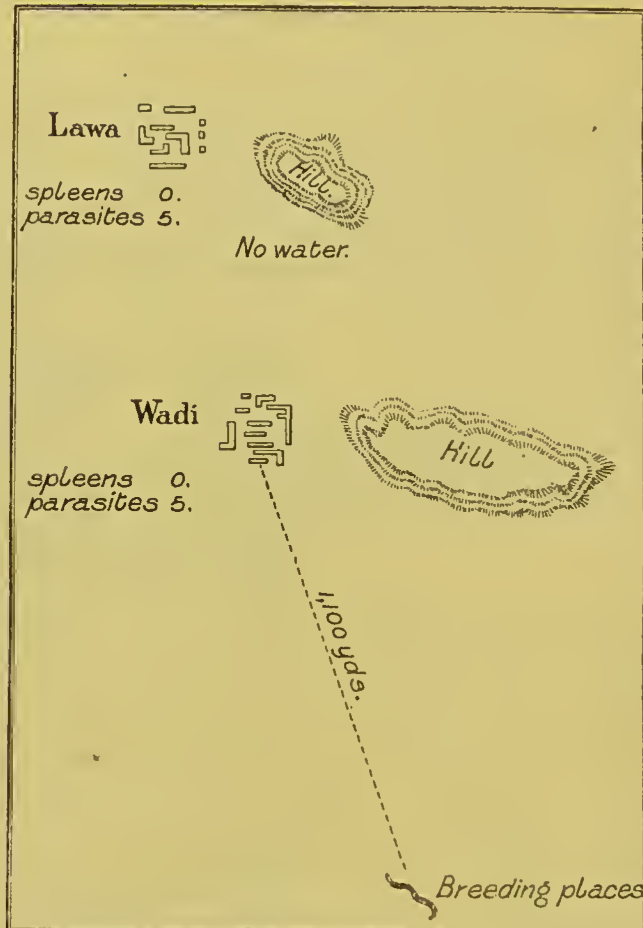

①
200 yds.
③
Lake
300 yds.
600 yds.
Ambajheri
②
spleens 5%.
parasites 25%.

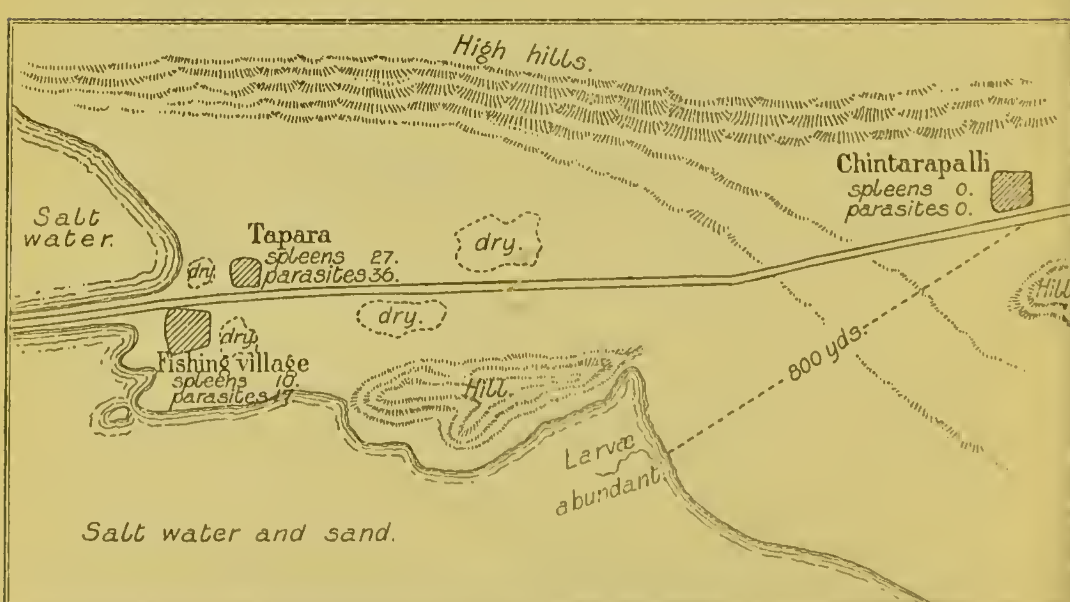

Tank.
A.Fuliginosus
Ridge.
½ mile
Takli
spleens 15.
parasites 15.

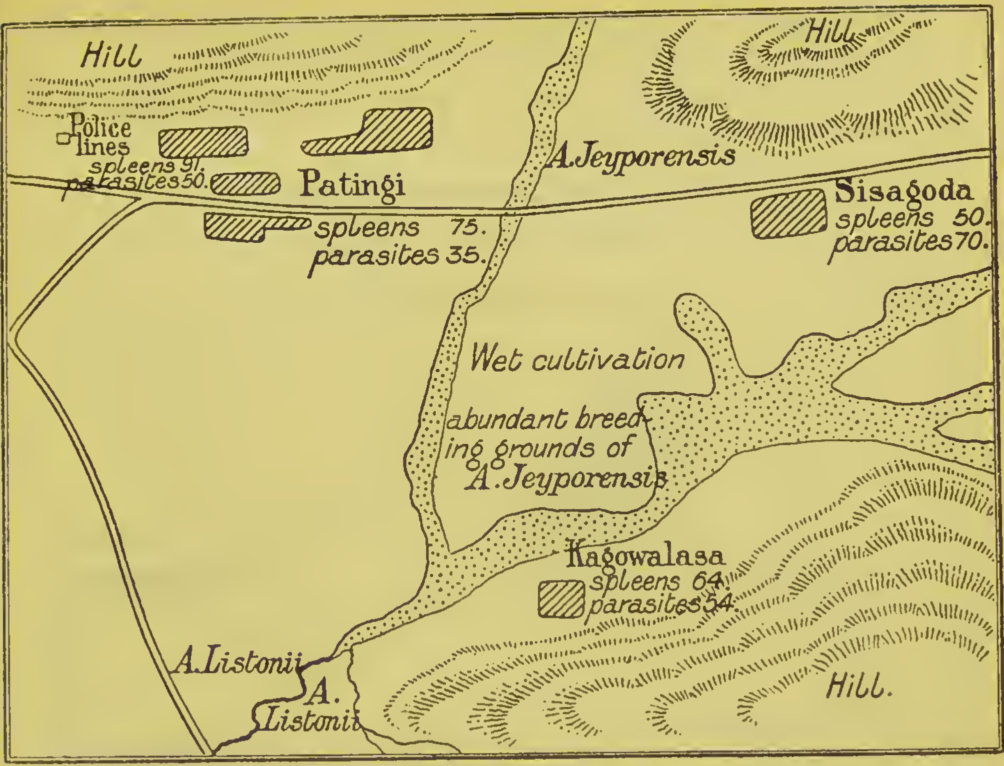

Swarming Larvæ.
¼ mile
Angini
spleens 40.
parasites 25.

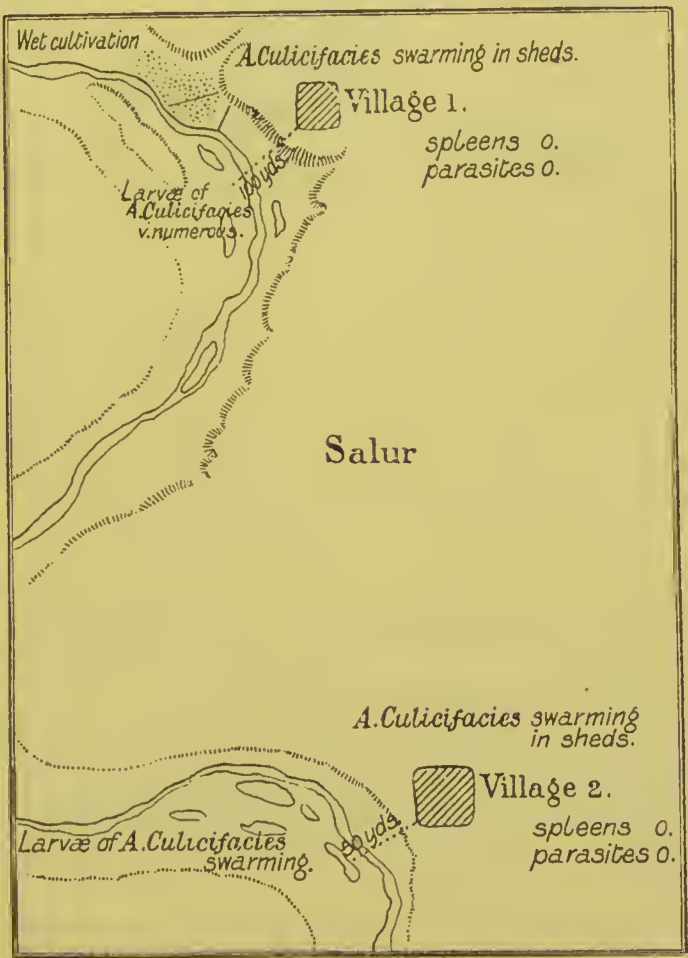

dried puddle.
Well
Sunegaon
spleens 0.
parasites 8·3.


spleens 15.
parasites 15.
Tank.
Sakadara
yds 50
Larvæ not very numerous in tank.
Shallow pool by village = A. Rossii larvæ.
over 1 mile.
Bighori
Several deep wells round village.
A. Culicifacies scanty.
spleens 0.
parasites 30%.


Lawa
spleens 0.
parasites 5.
Hill.
No water.
Wadi
spleens 0.
parasites 5.
Hill
1,100 yds.
Breeding places


High hills.
Chintarapalli
spleens 0.
parasites 0.
Salt water.
Tapara
spleens 27.
parasites 36.
dry.
dry.
dry.
dry.
Hill
Fishing village
spleens 10.
parasites 17
Hill.
800 yds.
Larvæ abundant.
Salt water and sand.

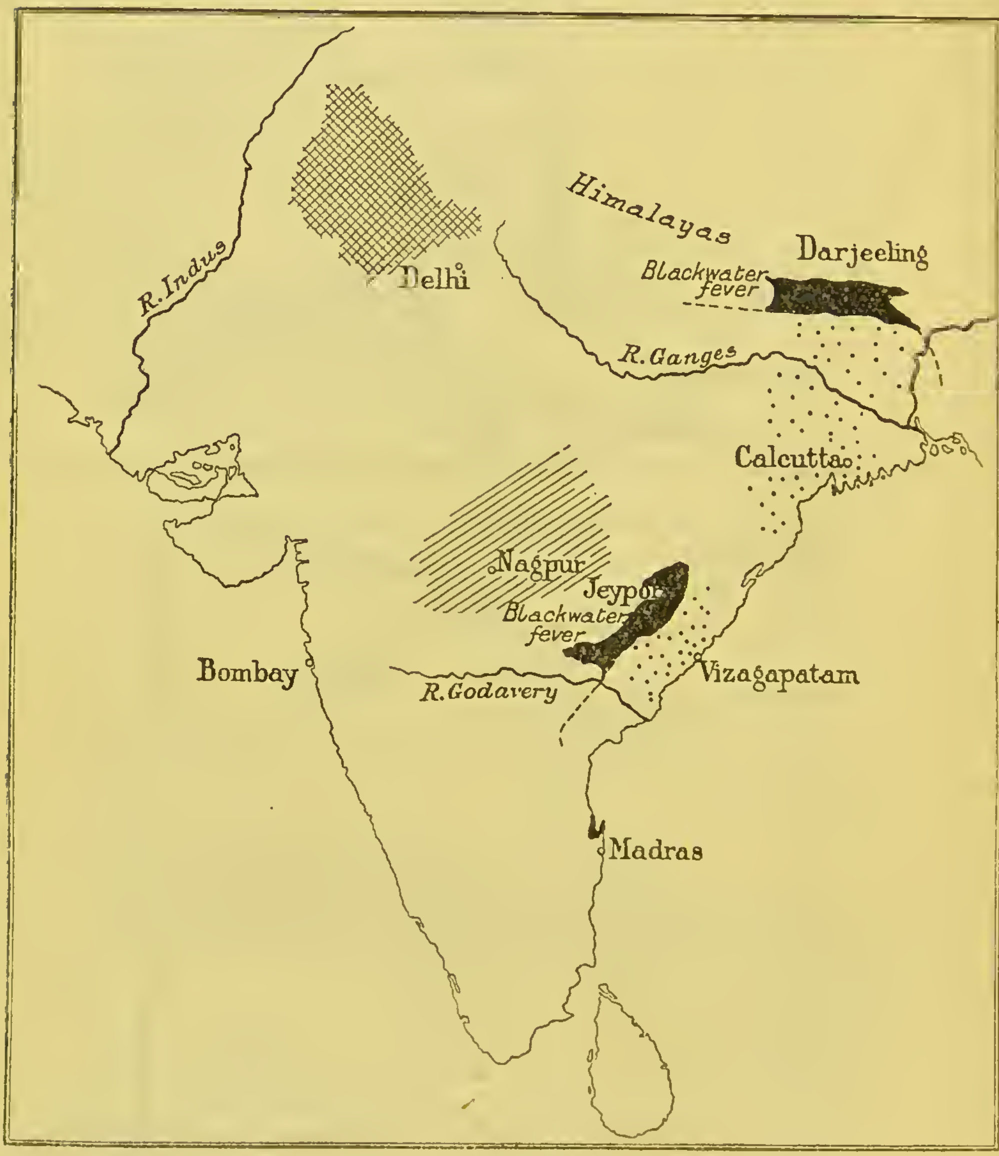

Hill
Police lines
spleens 91.
parasites 50.
Patingi
spleens 75.
parasites 35.
A.Jeyporensis
Hill
Sisagoda
spleens 50.
parasites 70.
Wet cultivation
abundant breeding grounds of A.Jeyporensis
Kagowalasa
spleens 64.
parasites 54.
A.Listonii
A. Listonii
Hill.


Wet cultivation
A.Culicifacies swarming in sheds.
Village 1.
spleens 0.
parasites 0.
Larvæ of A.Culicifacies v.numerous.
Salur
A.Culicifacies swarming in sheds.
Village 2.
spleens 0.
parasites 0.
Larvæ of A.Culicifacies swarming.

The variations in the endemic index under conditions varying with regard to breeding places are as seen in the table (Table I).

It is evident that in this district there is a close relationship between he distance of breeding grounds and

(1.) The number of anopheles in the houses.
(2.) The endemic index.



Villages may be considered in three classes.

1. Those with extensive breeding grounds close at hand, plentiful anopheles in the houses, and a high endemic index and spleen rate. In the above series, Phutala exemplifies these conditions, and was quite exceptional in the Nagpur district, the endemic index being 50 (January).

2. Those with extensive breeding grounds up to quarter of a mile

Table I.—To show Relation between the Distance and Extent of Breeding Places, the Number of Anopheles in the Houses, and the Amount of Malaria.

	Villages.	Parasite rate.	Spleen rate.	Species of anopheles found.	Distance and extent of breeding grounds.
Type 1.	Phutala	45	50	*A. culicifacies*, *A. fuliginosus* } Very abundant	Extensive. Less than 50 yds.
	Sakadara	15	15	.. ..	*A. Rossii*, *A. fuliginosus* } Not very abundant. Less than 50 yds.
	Digdoh	20	25	*A. culicifacies.* [*A. fuliginosus*] Very abundant	100 yds. distant.
	Leendra	20	0	*A. culicifacies*, *A. fuliginosus* } Abundant	200 yds. distant.
	Ambajheri	25	5	*A. fuliginosus.* [*A. culicifacies*] Abundant	200 yds. distant.
	Angini	25	40	*A. culicifacies*, *A. Stephensi*, *A. fuliginosus* } Very abundant	¼ mile. Very extensive.
	Babulkera	—	20	*A. culicifacies*, *A. Stephensi*, *A. fuliginosus* } Very abundant	¼ mile. Extensive.
	Takli	15	15	*A. Listonii*, *A. culicifacies*, *A. fuliginosus* } Scanty	¼ mile. Extensive. Ridge intervening.

	Villages.	Parasite rate.	Spleen rate.	Species of anopheles found.	Distance and extent of breeding grounds.
Type 1.	Telankeri	10	5	*A. fuliginosus.* Scanty	$\frac{1}{4}$ mile. Inextensive. Trees intervening.
	Kaamla	7	0	*A. culicifacies* / *A. Stephensi* } Scanty	$\frac{1}{4}$ mile. Inextensive.
Type 2.	Sunegaon	8	0	*A. Stephensi.* Scanty	No breeding places within $\frac{1}{2}$ mile. Dried-up buffalo wallow within 50 yds.
	Bighori	30	0	*A. culicifacies.* Scanty	No breeding place within $\frac{3}{4}$ mile.
Type 3.	Lawa	5	0	Nil	Breeding places over $\frac{1}{2}$ mile.
	Wadi	5	0	Nil	Breeding places over $\frac{1}{2}$ mile.

away. These also generally have numerous anopheles in the houses, and a moderately high endemic index. The endemic index in the Nagpur district under such conditions was on an average 25 per cent. (January).

3. Those with breeding places over half a mile distant. These showed:—

a. Anopheles not to be detected and a much reduced endemic index (5 per cent., or in some cases 0 per cent.).

b. A variable number of anopheles in the houses, and often a considerable amount of malaria.

We shall consider further this latter class of villages, as they are of considerable interest, and as we have already recorded in Africa conditions which seem exactly parallel. Though at first sight the presence of malaria in such villages is hard to account for, yet the explanation is, we believe in every case, a very simple one. In our second report (Gold Coast), we described the conditions found by us in a small isolated hut on the bed of a dried lagoon. We were able here to trace clearly the following cycle of events, which probably gives the clue to the apparent anomaly of malaria existing where there are no breeding grounds. When first visited, the hut had several shallow pits close at hand, and numerous anopheles were caught. Later the pools dried up, and there were then no breeding places anywhere in the neighbourhood. Anopheles were still caught, however, several weeks later. Later still they decreased in numbers, but the children still showed a high infection. In the accompanying table many examples of such a condition are shown.

Presence (quantity) of Winged Anopheles.

There are the following types of villages:—

Class A. Including—

1. Those with no anopheles and no malaria.
2. Those with anopheles more or less abundant, and a varying endemic rate.
3. Those with anopheles scanty or absent, and yet often with a fairly high endemic rate.

Class B. Villages with abundance of anopheles, and yet no malarial infection.

Examples of type (1), Class A, are Wadi, Lawa, and Chintarapalli (see maps, p. 28). It appears clear that an absence of breeding grounds within half a mile continued throughout the year or for long periods (many months) is sufficient to ensure an absence of anopheles, and so little or no malaria.

Observations on villages of this type have indirectly thrown light on the question of the distance of flight of anopheles. In many

Table II.—Showing the continuation of Anopheles after Breeding Places have Dried up and Presence of "Residual" Malaria.

		Parasite rate.	Spleen rate.	Anopheles in houses.	Breeding places at time of observation.	Signs of extensive breeding grounds some time previously.
District 1. Accra. Gold Coast.	Outer portions of Accra ..	—	—	Abundant................	Yes	Yes.
	Accra town	70	—	Scanty	Scanty	Yes.
	An area in Accra	31	—	No......................	No	No.
	Cantonment	63	—	Scanty	No	Yes.
	Houssa village	—	—	Very scanty....	No	Yes.
	Village, north end........	69	—	—	No	
	" south end.........	61	—	Abundant	Yes	Yes.
	Isolated hut on lagoon bed—					
	April	—	—	Abundant................	Yes	
	May.............	—	—	Abundant................	No	
	June	—	—	Abundant................	No	
District 2. Mian Mir. Punjab.	Inniskilling bazaar	52	80	Abundant *A. Rossii* and *A. culicifacies*	Yes	Yes.
	Royal Artillery bazaar— October	35	75	Abundant *A. Rossii*, scanty *A. culicifacies*	No	Yes.
	December.........	29	34	*A. Rossii* scanty, *A. culicifacies* not seen	No	Yes.
	Syce lines, 51st Battery— October..........	—	—	Abundant *A. Rossii*, abundant *A. culicifacies*	Yes	
	November.........	56	48	Very scanty *A. Rossii*	No	No.
	December.........	12	30	No anopheles	No	No.

		Parasite rate.	Spleen rate.	Anopheles in houses.	Breeding places at time of observation.	Signs of extensive breeding grounds some time previously.
District 2. Lahore. Punjaub.	Syce lines, 54th Battery, November	20	20	No anopheles found	No	Doubtful, nearer than 600 yards.
	Cavalry lines—					
	November.........	24	36	*A. Rossii* very scanty........	No	Yes.
	December.........	—	11	ditto	No	
District 3. Vizagapatam.	Vizagapatam busty.	0	0	No.......................	No	No.
	Tapara	27	36	Scanty	No	Yes.
	Fishing village....	10	17	Scanty	No	Yes.
	Chintarapalli	0	0	No......................	No	No.

statements on the flight of mosquitoes, it would appear that they apply to culex. The question ought to be determined if possible, however, for the different species of anopheles, as considerable differences in the power of flight may well exist. In the villages in Nagpur the three common species are (December, January, and February) *A. culicifacies*, *A. Stephensi*, and *A. fuliginosus*. Where their breeding places are not removed over a quarter of a mile, all these species are found in abundance in houses. Much over a quarter of a mile, however, they do not occur; and at half a mile from extensive breeding places, houses contain few or none. At Mian Mir we failed after prolonged search to find any winged anopheles in huts 600 yards from breeding places. We may say with some certainty that *A. culicifacies*, *A. Stephensi*, and *A. fuliginosus* readily fly a quarter of a mile, but they do not in any numbers traverse half a mile.

The character of the land intervening undoubtedly has a great influence in this respect. This is especially noticeable in the case of villages with belts of trees between them and distant breeding grounds. The trees in this case form a protective screen.

In the second and third types of Class A, breeding grounds are either present, or there may be found signs that breeding grounds have more or less recently dried up, or the conditions are such that extensive breeding grounds must have existed during the rains. These two latter are exceedingly common conditions, and a clear realisation of the process concerned much simplifies observations on the relation of anopheles to malaria.

We have in these cases, so to speak, residual anopheles remaining behind a considerable time after their breeding places have disappeared, and only very gradually diminishing in numbers. Associated with this, we have a residual malarial infection, and this appears to persist still longer than the anopheles. Some degree of this condition is perhaps the commonest of all conditions found in villages in the dry season.

Class B.—Abundance of anopheles with no endemic malaria.

Nuttal, Cobbett, and Pigg showed, in 1900,* that in the fen districts and elsewhere in England, *Anopheles maculipennis* were abundant, though presumably malaria is not now present.

Celli has also recorded areas where anopheles are abundant and imported fever cases frequent, yet there is no dissemination of malaria. In the outskirts of Calcutta we found abundance of anopheles (*A. Rossii*), yet no endemic malaria. Further we have in Salur, Madras, and a village near Vizagapatam two instances of this kind.

At Salur, *A. culicifacies* (which elsewhere has been found infected by us) occurs in profusion, the breeding grounds being close at hand and extensive, yet there is no splenic enlargement and no malarial

* 'Journal of Hygiene,' vol. 1, No. 1.

infection. The possibility of infection from a neighbouring area of high infection is a constant one, yet there is no malaria there. Further observation of similar instances are necessary before any explanation can be satisfactory.

Summing up, these observations show that, except in certain peculiar instances, in any one district a direct relationship exists between the extent and proximity of breeding grounds, the number of anopheles, and the amount of malaria.

Species of Anopheles.—Nuttal has drawn attention to the importance of species in matters relating to the life-history of anopheles. Daniels has suggested the possibility of species being important.

Our reports on the natural history of Indian anopheles show that the habits of different species differ. Further, from a consideration of the ova, larvæ, and adult insects, we have been able to divide Indian anopheles into several natural and distinct groups.

In an accompanying report we have given the facts which led us to conclude that the species of anopheles was an important factor in determining the carrying of infection. Briefly they were of two kinds :—

Firstly, two species have been dissected by us in two different localities under identical conditions of capture, and of these *A. culicifacies* has in both instances carried sporozoits while *A. Rossii* has not. Experimentally we have shown both species will develop sporozoits, but this does not invalidate the result of our dissections in which a most undoubted difference in the sporozoit rate is shown in the two species.

Secondly, we find in regions of high endemicity that the carriers of infection belong to a group of mosquitoes which have common characteristics. They are small dark anopheles with unbanded legs. They include *A. culicifacies*, *A. Christophersi*, *A. Listonii*, *A. Indicus*, *A. Jeyporensis*. It is noteworthy that *A. Christophersi* found by us in the high endemic area of the Duars is closely allied to, but not identical with, *A. funestus*, the African species, which is the carrier in many parts of tropical Africa. It is closely allied also with *A. Jeyporensis* found by us in the high endemic area of the Jeypore agency.

We may also remark that since leaving the Duars we have not encountered *A. maculata.** This species does not appear to occur in the Bengal plains, in the N.W. Provinces, the Punjab, or the Central Provinces with its rich anopheles fauna. In the Jeypore hills, however, we again met with this species. At Sam Sing (3000 feet), Bengal Duars, this species was found alone and associated with an endemic index of 25.

The anopheles fauna of the Duars and the Jeypore hills, two regions of intense endemicity, is almost identical.

* In Report VI, *A. metaboles* has throughout been erroneously printed for *A. maculatus*.

We can say that the abundance of anopheles has no relation to malaria when one species at least of anopheles, *A. Rossii*, only is concerned. The species of anopheles present indeed is, in all probability, a powerful determining cause of malarial endemicity.

Race and Social Status.

Considerable differences in this respect were encountered by us in the various villages examined. Thus we find:—

1. Aboriginal tribes living in hill districts.
2. Plains people living in the hills.
3. People of high caste living under good conditions.
4. People of low caste living under squalid conditions.

Koch has attributed to the importation of non-immune immigrants into an immune district an increase of fever and a gradual subsidence of the fever rate as immunity is again acquired.

We, however, find intense malarial infection also among aboriginal tribes, where this factor is not in operation. Indeed, many of our highest endemic indices have been encountered in aboriginal villages. The presence of a high endemic index does not therefore depend upon an importation of strangers. (Table III.) The same condition of intense malaria also prevails in villages of plains people in the hills.

Children of low social status frequently showed a high malarial infection. This is no doubt partially due at any rate to their squalid dwellings being suitable for anopheles. People of very low social status and living in very squalid conditions are, however, often found with little or no malaria, *e.g.*, Calcutta, Vizagapatam.

It is difficult to assign a value to racial apart from regional factors, as there is the association of aboriginal tribes and hill districts. The fact that a village of plains people also showed high infection seems to point to race not being the factor involved.

Seasonal Variation.—This is well illustrated by the examples from Mian Mir, Punjab. Here the supply of *A. culicifacies* is entirely from the irrigation canals. The variations in temperature are here extreme (from 120° F. in the shade during the hot weather to a minimum of 40° in December). Besides the effect of temperature in diminishing the number of larvæ, we have to allow for the fact that the canals are periodically shut off with a resulting marked decrease of larvæ.

It may be noted here that in the Sycc lines (Table IV), though the most careful search was made, no anopheles, not even *A. Rossii*, could be found. We had here, therefore, a residual infection in the absence of anopheles, and with the onset of the cold weather a continued absence of anopheles and a still further reduction of the infection. The seasonal variation in the Punjab is unusually well marked.

Table III.—Race and Social Status.

Village.	Race.	Situation.	Parasite rate.	Spleen rate.	Remarks.
Jeypore. Sunki	Pariah, plains people	In hills within high endemic area	50	55	15 miles apart only. Villages apparently do not contain aborigines.
Salur	Ditto	In plains in low endemic area	0	0	
Police lines	Plains people	In hills within high endemic area	50	91·6	
Bodawalasa	Aboriginal tribe, Parasas	Ditto	86	57	
Kagowalasa	Ditto, Gadobas	Ditto	50	63	
Kanai putti	Ditto, Malis	Ditto	50	69	
Village A	Telugu, fisher caste	Coast lands, Vizagapatam	0	0	Variations dependent on local conditions.
,, B	Ditto	Ditto	10	17	
,, C	Telugu, agricultural caste	Ditto	27	36	
,, D	Ditto	Ditto	0	0	
Simachelam	Telugu	In hills, 800 feet	..	25	
Madras	Tamils	In Blacktown	5	0	Same race with different local conditions.
Ennur	Ditto	Coast lands	54	95	

Table IV.—Showing Influence of Season in the Punjab (Mian Mir) (Cold and Dry Weather).

	Oct.	Nov.	Dec.	Remarks.
Inniskilling bazaar—				
Parasite rate	52	20	..	Breeding places still in existence.
Spleen rate	80	38	..	Larvæ and anopheles diminished in Nov. and Dec.
Royal Artillery bazaar—				
Parasite rate	35	..	29	Breeding places absent.
Spleen rate	75	..	34	
Syce lines, 51st battery—				
Parasite rate	..	56	12	Scanty breeding places.
Spleen rate	..	48	30	
Cavalry lines—				
Parasite rate	..	24	..	Breeding places absent.
Spleen rate	..	36	11	

Altitude.—This of itself does not seem to play an important part under 4000 feet. In the mountain districts visited by us we have found two conditions.

1. Steep hill slopes intersected by mountain streams, which in the hot weather are frequently dry, and in the rains are rapid torrents. Under these conditions the facilities for breeding are reduced to a minimum, and in such cases malarial infection is almost nil. The Darjeeling tea gardens and Tonetta, near Mussoorie, N.W.P., are examples. (Table V.)

2. Small plateaus ensconced in the surrounding hills. Here there are numerous facilities for breeding in the swamps and rice fields, which are almost universally present under these conditions.

Sam Sing and Patingi are examples of this condition at a height of about 3000 feet. In these latter cases we find again often a high endemic index.

Regional Factor.—While then in the individual portions of a particular district we are able to ascribe the variations found to different factors which may practically be resolved into one, viz., the abundance or scarcity of the infecting species of anopheles, yet there remains the more difficult question of why one region should be highly malarial and another not. It is difficult to explain what Celli has termed "paludismus sine malaria." We have found parallel instances in India. In Bengal we have an area of low endemicity merging somewhat sharply into the highly malarious Duars. In Salur, Madras, we have innumerable *A. culicifacies*, with no enlarged spleens and no malarial infection, while 15 miles away at about 1000 feet the endemic index has already reached 50.

Table V.—Showing Relation between Altitude and Malarial Endemicity.

Region	Village.	Altitude.	Parasite rate.	Spleen rate	Anopheles and physical conditions.
		feet.			
Duars.	Rungamutty	800	43	83	Streams. Abundant *A. Christophersi.*
	Nagasuri	1200	55	82	Streams. Abundant *A. Christophersi* and *A. maculata.*
	Sam Sing	3000	28	7	Rice fields. Numerous *A. maculatus.*
Darjeeling.	Seypudura	2000	0	12	Springs. Scanty *A. maculatus.*
	Lower Singell garden, Kurseong	4000	0	5	*A. Rossii. A. maculatus.* Scanty. In huts.
	Upper Singell garden, Kurseong	4400	0	0	Swamp a few sq. yds. in area. *A. maculata. A. Lindesayi.* Scanty.
North-West Provinces.	Tonetta	6000	0	0	Spring. *A. Lindesayi.*
	Rajpore	3000	10	0	River bed. *A. maculatus* abundant.
Jeypore Hills, Madras.	Sunki	2000	50	55	Stream. Abundant *A. culicifacies* and *A. maculatus.*
	Patingi	2800	70	50	Marsh. Rice fields. Abundant *A. Jeyporensis.*
	Koraput	2000	20	70	Ditto.
	Koomba	2000	60	100	Ditto.

Table VI.—Showing the "Regional Factor."

Region.	Locality.	Parasite rate.	Spleen rate.	Common species of anopheles.
A region of low endemic index. Much swamp. Bengal	Calcutta	0	0	*A. Rossii.*
	Alipore	0	0	*A. Rossii.* *A. fuliginosus.* *A. sinensis.*
	Barrackpur	0	0	
	Belghuria	8	44	
	Ranaghat	14	0	
	Jalpaiguri (1)	16	27	
	" (2)	0	14	
A region of intense malarial endemicity (blackwater fever). The Duars	Mainaguri	25	74	*A. Christophersi.* *A. maculatus.*
	Rungamutty	43	83	
	Nagasuri	55	82	
	Nagrakata	72		
A region of high endemic index. The Punjab	Enniskilling, B	52	80	*A. culicifacies.* *A. Rossii.*
	Royal Artillery, B	35	75	
	Syce lines, A	56	48	
	Syce lines, B	20	20	
	Nat. Cavalry lines	24	36	
A region of not very intense endemic index, showing marked local variation. Central Provinces	Phutala	45	50	*A. culicifacies.* *A. fuliginosus.* *A. Stephensi.*
	Sakadara	15	15	
	Digdoh	20	25	
	Leendra	20	0	
	Ambajheri	25	5	
	Angini	25	40	
	Babulkiri	..	20	
	Takli	15	15	
	Telankeri	10	5	
	Kaamla	7	0	
	Sunegaon	8	0	
	Bighori	30	0	
	Lawa	5	0	
	Wadi	5	0	

Region.	Locality.	Parasite rate.	Spleen rate.	Common species of anopheles.
A region of low endemic index. Flat land near the coast. Northern Madras	Vizagapatam	0	0	*A. culicifacies.*
	Tapara	10	17	
	Chintarapalli	0	0	
	Fishing village	27	36	
	Lower Simachelam	5	10	
	Upper Simachelam	..	25	
	Salur (1)	0	0	
	,, (2)	0	0	
A region of intense malarial endemicity (and blackwater fever) sharply marked off from a low endemic region to the east. Jeypore Hill district	Sunki	50	55	*A. Jeyporensis* (closely related to *A. Christophersi*). *A. Listonii* (related to *A. Christophersi*). *A. maculatus.*
	Police lines, Patingi	50	92	
	Patingi	35	75	
	Bodawalasa	86	57	
	Kanaipatty	50	69	
	Kagowalasa	50	63	
	Sisagoda	70	50	
	Koraput	20	70	
	Police lines, Koraput	20	80	
	Koomba	60	100	
Area of intense malaria	Ennur	55	95	*A. culicifacies.* *A. Rossii.*
	Madras	5	0	*A. culicifacies.* *A. Rossii.*

Our observations have led us to conclude that a district may show a high endemic rate by reason of suitable local conditions (extensive breeding grounds close at hand) being repeated in the majority of the villages throughout the district. Were the physical conditions at Phutala reproduced in all the villages of the Nagpur district, we should get a district of fairly high endemic index.

The uniform presence of suitable local conditions is, however, quite insufficient to explain the data referring to regional variation. In regions of very high endemic index "dry" villages as well as "wet" villages exhibit extreme infection. In regions of low endemic index, the most suitable local conditions fail to give such a degree of infection as prevails in villages in intense malarial areas.

Phutala (Table I and Map), in the Central Provinces, though situated under conditions of the utmost suitability, fails to reach the rate of many "dry" villages in the Jeypore district or Duars. In very low endemic areas an abundance of anopheles seems incapable of giving rise often to any infection at all. In Bengal, villages surrounded by unlimited breeding grounds show extremely low endemic indices.

We have endeavoured to show that "species" is one determining factor. We have shown that *A. Rossii* is of little account in the spread of malaria, while certain other species are concerned in its transmission. How far variations in endemicity are due to this cause further work must show. Whether species of anopheles is the determining cause or not, we can say that over and above local conditions (the abundance of breeding grounds) there is another still more potent factor which we have called the "regional factor."

Conclusions.

1. That other things being equal there is a direct relation between the extent and proximity of breeding grounds, the number of anopheles in the houses, and the endemic index.

2. That where breeding grounds are half a mile distant and have not recently existed closer, malaria is reduced to a minimum and anopheles are not to be found in the houses.

3. That the flight of anopheles (*A. culicifacies*, *A. fuliginosus*, and *A. Stephensi*) in Nagpur, Central Provinces, is frequently a quarter of a mile but does not extend to half a mile.

4. That the relation between the number of anopheles and endemic malaria is greatly modified by the species of anopheles present.

5. That *A. Rossii* does not carry infection under conditions in which *A. culicifacies* does.

6. That in India, areas of extremely high endemic index are found sharply separated off from areas of low endemicity.

7. That the distribution of endemic malaria depends, even more

than on local conditions in regard to breeding places, on the district concerned, and must at present be attributed to undefined causes which we have termed the "regional factor." The regional factor may be largely due to species but more accurate and detailed observations on the distribution of anopheles and malaria are necessary before this can be decided.

8. That in the two regions of intense malaria visited by us (Duars and Jeypore hills), blackwater fever was well known and has attacked a large proportion of the resident Europeans.

"Note on Bodies in Salivary Glands of Anopheles," etc. By J. W. W. Stephens, M.D. Cantab., and S. R. Christophers, M.B. Vict. Received April 25, 1902.

[Plate 5.]

(1.) Bodies which are probably encysted sporozoa were first found by us in *A. Rossii* at Jalpaiguri, Bengal. They have also been seen by us in a dissection of *A. fuliginosus*, Nagpur, C.P. Captain James, I.M.S., also reports finding them in *A. Rossii*, Ennur, Madras.

The following note was made by us :—"*A. Rossii*—one lobe of salivary gland is replaced by a mass of short sausage-shaped bodies (sporozoa). A few also in the substance of a second lobe. None found in the stomach." On fixing and staining by Romanowsky's method they show—

(1.) A definite capsule (red). The capsule is frequently frayed out or has a perforated appearance.
(2.) There are generally two chromatin bodies embedded in.
(3.) Cytoplasm (blue).
(4.) The size is roughly $\frac{1}{3}$—$\frac{1}{2}$ that of a red blood-cell. (*Vide* Plate 5, fig. 1.) Their characteristic shape is that of a sausage. They are quite different from the sporozoa previously noted by us in the ovaries of *A. Costalis*, which have also been figured by Celli ; their nature is unknown to us. In the first instance they occurred actually in the gland substance ; in the other instances they were free.

(2.) Bodies apparently identical with Ross's black spores. They were seen by us in a dissection of the glands of *A. fuliginosus* made by a Burmese prisoner at Nagpur jail. As they appeared in the dissection they had no connection with any cyst, nor were they in the

salivary gland itself. Their appearance did not suggest that they were sporozoa.

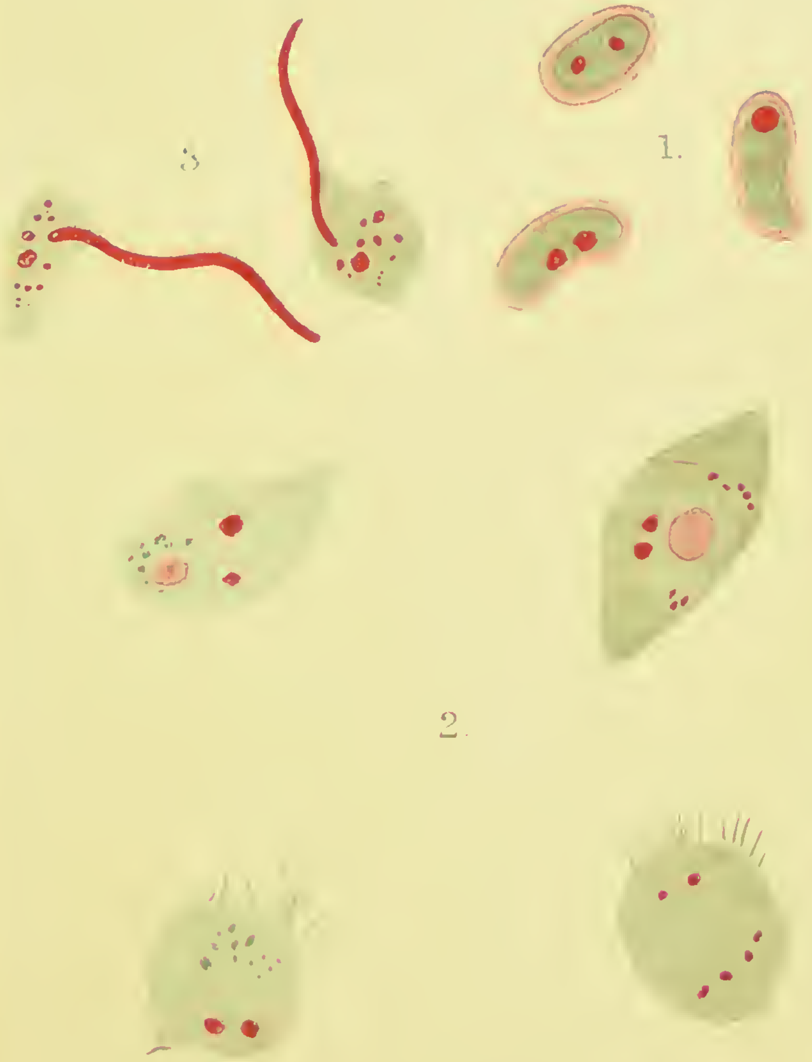
(3.) In dissecting the glands of anopheles from time to time, encysted bodies having apparently two sucking discs have been found by us in *A. Rossii* and in *A. fuliginosus.* They are probably the same as the bodies described by Italian observers as flukes.

(4.) Skin organisms—

(*a.*) Very commonly in blood films made in Jalpaiguri, especially in the children of a particular school, bodies were found which had the following characters:—They are spherical or irregular in shape, and vary in size from 7 μ to 25 μ. With the Romanowsky's stain they show (1) one or more chromatic bodies of different sizes, (2) a reddish area, (3) a protoplasm staining blue or purple (hazy), (4) a distinct fringe of cilia is distributed all around or confined to one area. (*Vide* Plate 5, fig. 2.)

(*b.*) Bodies with a long and thick flagellum. They are pear-shaped or irregular. They show, with Romanowsky, chromatin particles. They occur commonly in certain districts as a skin contamination in blood films. (Plate 5, fig. 3.)

(*c.*) Very minute rings or discs about one-third the diameter of the youngest ring form of malaria parasite. Though a chromatic particle can be made out, the "vacuolic" nuclear area of the malaria parasite cannot be distinguished. They may occur on the blood-cell, but most frequently free. They have a flatter appearance than malaria parasites and are more minute. They disappear when great care is taken in cleansing the finger.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1.
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"On a Convenient Terminology for the Various Stages of the Malaria Parasite." By E. RAY LANKESTER, M.A., F.R.S., Director of the Natural History Department, British Museum. Received February 20,—Read March 6, 1902.

I have found it necessary in labelling a series of models of the malaria parasite in the Central Hall of the Natural History Museum to use as simple and clear a terminology as possible. I think that this terminology will be found useful by others who are perplexed by such terms as "sporozoites," "blasts," "ookinetes," "schizonts," "amphionts," and "sporonts"—terms which have their place in schemes dealing with the general morphology and life-history of the group Sporozoa, but are not, as experience shows, well suited for immediate use in describing and referring to the stages of the malaria parasite.

It is necessary to treat the malaria parasite from the point of view of malaria; that is to say, to consider its significant phases to be those which it passes in the human blood. In reality its mature condition and most important motile, as well as its most prolific reproductive, phases are passed in the body of the mosquito.

1. The malaria-germ which is brought by the stab of the Anopheles into the human blood-vessels is a reproductive particle, a *spore*. It is needle-like in shape, and might be named in reference to its form (*e.g.*, oxyspore or raphidiospore), but the most important fact about it for description and comparison is that it has been formed *outside* the human body, and is introduced as a strange element into the human blood by the agency of the mosquito. I therefore call it the EXOTOSPORE.

2. The Exotospores (probably as many at a time as forty or fifty) enter the blood by the agency of the mosquito's stab and immediately penetrate, each one, a red corpuscle. The history of this process has not been observed. As soon as it has entered a red corpuscle the exotospore loses its needle-like shape and becomes amœbiform. I apply to it the name I proposed some years ago for similar amœbiform spores in other Protozoa, namely, AMŒBULA.*

3. The Amœbula exhibits amœboid movements within the red corpuscle, enlarges and finally breaks up into spherical spores, which are liberated with destruction of the red corpuscle. It seems to me unnecessary to have a special name for the star-like or other condition of the Amœbula when in course of breaking up into spores; but the spores so produced require a special name which shall emphatically distinguish them from the Exotospores. I call them the ENHÆMOSPORES, in reference to the fact that they are produced by a

* 'Encycl. Britann.,' Article "Protozoa."

process of division which occurs *in* the blood of the malaria-stricken human being.

4. The Enhæmospores penetrate fresh red blood-corpuscles, and after a certain growth as amœbulæ break up into a new crop of Enhæmospores, by which the infection of the red corpuscles is extended. This process appears to go on for several generations and for a varying duration of time. But owing to conditions and at a period of the infection which has not been precisely ascertained, some (or all ?) of the amœbulæ derived from Enhæmospores cease to break up into spores. Instead of carrying out that process they enlarge, and in the case of the æstivo-autumnal parasite (*Laverania præcox*) become sausage-shaped or, as it has been termed, crescent-shaped. This change of form is accompanied by a destruction of the red corpuscle and the formation of granules of dark pigment within the parasite. It seems best to term this phase the "CRESCENT" or "CRESCENT-SPHERE," the latter term being applicable to those species in which the form is not markedly crescentic.

5. The crescents or crescent-spheres remain quiescent in the human blood. They are, however, of two different natures—male and female. It is not possible to distinguish with any certainty the male from the female crescents whilst they remain in the human blood-vessels. But it is these bodies which are destined to be swallowed by the Anopheles mosquito, and to carry on further the life-history of the parasite.

The crescents are therefore the sexual phase of the parasite. When the crescents are swallowed by a mosquito (of an appropriate species), they undergo two different modes of development, determined by the fact of their sex. Both sexes become spherical, and may now be called respectively "EGG-CELL," and "SPERM-MOTHER-CELL."

From the periphery of the SPERM-MOTHER-CELL, now floating in the mosquito's stomach, there are developed with surprising rapidity six or seven SPERMATOZOA, which for a time remain attached to the residual mass (or SPERM-BLASTOPHOR) of the sperm-mother-cell. Complete cytological study of this development is still wanting, but it appears that the spermatozoa are true spermatozoa, like those of the higher animals, and have the same relation to the mother-cell from which they develop as is the case in such an animal as the Earth-worm.

The EGG-CELL, now also floating in the mosquito's stomach, apparently gives rise to one, and possibly to two, polar bodies, but the observations on this point are, as yet, insufficient.

Fertilisation of the egg-cell now takes place in the gnat's stomach. A single spermatozoon penetrates and fuses with each egg-cell.

The fertilised egg-cell is spoken of as a "zygote"; it is also described as the sexually produced embryo.

6. The ZYGOTE or SEXUALLY PRODUCED EMBRYO remains unicellular, but increases in size and becomes pyriform. It exhibits active move-

ments of expansion and contraction in the line of its long axis, and also a quick movement of its narrower end alternately to either side. This is the largest growth of the individual cell attained to in the series presented by the life-history of the malaria parasite. It has been called "vermiform" and "vermicule" (Ross), and I adopt this name for it, viz., the VERMICULE. The vermicule is the dominant individual form in the history of the malaria parasite, endowed with greater size, power, and activity than other phases. It corresponds, not only in this respect, but also in its position in the life cycle, to the large often active cells of the Gregarinidea, which I proposed some time ago to call the Euglena-phase.*

It is worthy of note that in the size and activity of the Vermicule, the Hæmaosporidia—the order of Sporozoa which embraces the malaria parasite—come nearer to the Gregarinidea than they do to the Coccidiidea, though in the existence of a sexual generation absent in Gregarinidea, they agree with the Coccidiidea.†

The vermicule now pushes its way through the tissues of the gnat's stomach and in the blood sinuses outside the stomach becomes spherical. It enlarges and nourishes itself on the insect's blood, and forms a spherical CYST, or structureless transparent envelope. This cyst is destined to enlarge, with vast increase of its living contents.

The living cell within the cyst breaks up by a definite process to form eventually an immense number of exotospores, the stage with which the present description commenced. The CYST would most conveniently be called a "sporocyst," since, as so often happens in Protozoa, it is formed purely and simply in relation to the quiescence of the organism and its division into numerous reproductive spores. Unfortunately, the word "sporocyst" has been employed recently by writers on the Sporozoa for the small capsules containing one or two to eight elongated spores which used to be called "pseudonaviculæ," and are formed *within* such larger cysts as that now in question. The word "cyst" should have been reserved for the larger more general protective envelope, and the "pseudonaviculæ" might have been called "sporo-thekæs." In any case, I think we may call the cysts in which the vermicules of the malaria parasite enclose themselves "SPORE-CYSTS" or "SPORE-FORMING CYSTS." The name "oocyst," applied to them by some writers, is simply misleading.

7. The spore-cysts lying outside the stomach wall of the mosquito bathed in the insect's blood receive abundant nourishment. The single-celled vermicule enclosed undergoes rapid changes; it increases greatly

* 'Encycl. Britann.,' Article "Protozoa."

† A sexual phase has been described in the Gregarine Stylorhynchus by Léger since this paper was written. It occurs at an unexpected point in the cycle: two encysted full grown "Sporonts" are stated to produce the one egg-cells the other spermatozoids!

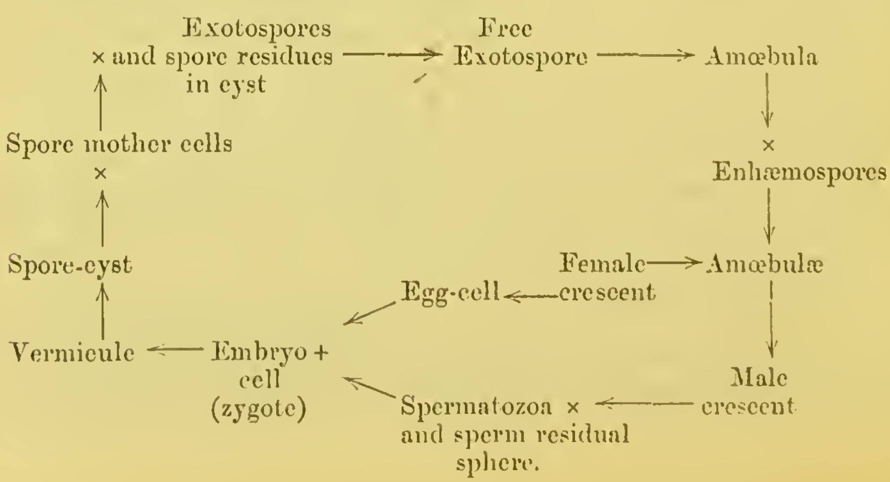
in volume and breaks up by normal cell division (? the earliest steps have yet to be studied) into a number of SPORE-MOTHER-CELLS. In the process of this division and the later stages of the final development of the "spores" (exotospores), the "spore-forming cyst" increases in size to twenty times its initial diameter.

The spore-mother-cells are set closely together in the cyst; they are of polygonal shape, owing to pressure, and each has its nucleus. Finally they give rise, each spore-mother-cell, to a crop of filiform spores (exotospores) which have the same relation to the spore-mother-cell as spermatozoa have to a sperm-mother-cell, viz., they form on the outside of the spore-mother-cell as outstanding processes, carrying away all the chromatin of the mother-cell and leaving in the centre or to one side a "residuary body," a "spore blastophore" similar to the "sperm-blastophore" of spermatozoon-development.

Thus we are brought back to the needle-like exotospores with which we started.

The spore-holding cysts burst and liberate the exotospores into the blood of the mosquito. Thence they readily pass into the ducts of the salivary gland, and so are conveyed by the mosquito's stabbing beak into human beings. A point in this connection is the definite ejection by the mosquito of the secretion of its salivary gland into the punctured wound which it makes in the human skin. There can be no doubt that such an ejection takes place. The leech ejects a secretion on to the wound caused by its bite which has the property of preventing the coagulation of the blood. It is possible that the mosquito and other blood-sucking flies may use the salivary secretion for the same purpose. It is obvious that unless there were some injection into the wound on the part of the fly, the chances of infection of the bitten animal by the parasites carried by mosquitoes or tzetze fly would be very small.

Our cycle of forms with the names here made use of may be written as below. The sign × is used to indicate fissile multiplication, and + to indicate fusion, while → merely indicates continuity.



	Malaria.	Coccidium.	Gregarina.
1.	Exotospore, free in human blood ("Blast" of some authors.)	Sporozoite	Sporozoite. (Filiform young.)
2.	Amœbula, in red corpuscles	Schizont	Amœbula.
3.	Enhæmospore, ditto, and in blood	Merozoites, formed by schizogony	
4.	Crescent, in human blood	Gametocytes	
	a. Male	Microgametocyte	
	b. Female	Macrogamete	Schizogony rare: sexual stages NOT OBSERVED and probably WANTING.
5.	Sperm-mother-cell, in gnat's stomach	Microgametocyte	
6.	Egg-cell, in gnat's stomach	Macrogamete	
7.	Spermatozoon, in gnat's stomach	Microgamete	
8.	Zygote or embryo-cell, in gnat's stomach	Young oocyst (sporont)	
9.	Vermicule, in gnat's stomach	WANTING (Called "ookinete" or "kineto-sporont" in the nomenclature of this column.)	Full-grown motile "gregarine." (Euglenoid phase.)
10.	Spore-cyst, in blood-sinus outside gnat's stomach	Older (but not larger) oocyst or sporont	Cyst enclosing one or two full-grown sporonts.
11.	Spore-mother-cells in cyst, in blood-sinus outside gnat's stomach	Sporoblasts (sporogony)	Sporoblasts. (? Conjugation in *Lankesteria Ascidiæ.* Spermatozoa and ova in Stylorhynchus.)
12.	Exotospores in cyst, in blood-sinus outside gnat's stomach	Sporozoites enclosed in small groups in sporocysts within the bigger oocyst.	Sporozoites enclosed in capsules, called "pseudonaviculæ" or "sporocysts."
21.	Free exotospores, in gnat's salivary duct	Free sporozoite	Free sporozoite.

I also give a list of the names here used with reference to the occurrence of the forms indicated in man or in gnat and an indication of the corresponding stages in a Gregarina and a Coccidium. In the column belonging to coccidium I have employed the generalised physiological nomenclature accepted by special students of the Sporozoa (Schaudin, Lühe, &c.)

ROYAL SOCIETY.

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Report by Capt. JAMES, I.M.S.

REPORTS BY MESSRS. STEPHENS AND CHRISTOPHERS.

"The Occurrence of Blackwater Fever in India." By J. W. W. Stephens, M.D., Cantab., and S. R. Christophers, M.B. Vict. Received October, 1901.

Much has been written on the subject of blackwater fever which has tended to obscure the subject. Especially has stress been laid, by those who deny its malarial origin, on its peculiar distribution. It is pointed out that the distribution of malaria and blackwater fever do not coincide. Thus it has been stated that "Algeria," although a deadly malarial country, presents no cases of blackwater. The following passage, however, from Kelsch and Kiener* contradicts this: "L'hæmoglobinurie n'est pas exclusivement née aux fièvres bilieuses des pays chauds. Nous avons déjà signalé son apparition assez fréquente dans les fièvres d'Algérie." Again, much stress has been laid on the supposed fact that blackwater does not occur commonly in India, though a highly malarial country, and that blackwater in India is a new disease—for it has happened that, from certain districts of India, within the last few years, some few cases of blackwater fever have been reported in the medical journals.

In reference to this it may be pointed out that the same idea was held in British Central Africa and West Africa, that the disease was of recent introduction. The French statistics for Gorée, however, sufficiently disprove this for West Africa. They embrace the period 1864—1870—

	No. of cases.	Deaths.
Fièvre bilieuse hématurique	109	35
Malaria (pernicious attacks)	89	51

To inquire personally into the prevalence of blackwater fever in particular districts would take much time, but we have ample evidence to show that blackwater fever is not an unknown disease in certain parts of India.

* 'Maladies des Pays Chauds,' p. 316.

Though no systematic inquiry has been undertaken by us, we have collected evidence which shows that blackwater fever exists in Assam, in the Duars (Bengal), in the Terai (Bengal), and in Madras, while isolated cases have occurred at widely separate places in India.

Calcutta.—One of the physicians at the Medical College informed us that he had seen 4 cases. Father and daughter (2), European (1), Eurasian (1).

The pathologist to the Military College informed us that he believed he had suffered from hæmoglobinuria twice, once in the Punjab, once in Calcutta.

One of the physicians at the Sealdah Hospital informed us that he saw one or two cases in hospital during the year.

The cases from Calcutta in all probability did not originate in Calcutta, but most probably came from outlying districts.

Barrackpore.—This is 9 miles from Calcutta. The following is an extract from the report of the medical officer in charge of the Station Hospital :—" Patient states that he has had a previous attack at Rawal Pindi, but there is no record of it. October 27, 1900. Urine blackish-red. Microscopically no blood corpuscles. On the 30th, urine nearly normal. November 1, 1900. A relapse, urine smoky black colour. Two other men in hospital also passed dark-coloured urine. In one case it was transitory. In the other case it was very persistent and continued for weeks. The patient had an enlarged spleen, and the typical appearance of malarial cachexia. I put him upon quinine and it stopped the fever and the hæmoglobinuria. He was free from both for several weeks, when again he got an attack of fever accompanied by urine of smoky black colour. I do not think this condition can be so uncommon as is generally stated. It is certain that it can be easily overlooked, it is in fact impossible to detect it unless the urine is collected in a vessel, which is the exception. I noticed one case in hospital in 1899 and another in a private patient."

Hazaribagh.—Captain Maynard reports a case.

Meerut.—A case has been reported from here.

Roorkee.—Station Hospital, 1900. There was an admission for hæmoglobinuria. The disease was of the intermittent type. The urine passed was blood coloured. Under the microscope no blood cells were detected.

Statistic of the Army and Prisoners in India.

The Principal Medical Officer of His Majesty's forces in India informed us that he had had blackwater himself, and that it occurred in the army. It should be noted, however, in this connection, that no separate heading "Blackwater fever" occurs in the nomenclature of diseases employed, that even if recognised it is quite possible or probable that the hæmoglobinuria might be returned under the

heading "Ague" or "Remittent fever," which is the classification of malarial fever employed. It might even be returned simply as "jaundice." It may also be questioned whether some of the entries under the heading "hæmaturia" were not really cases of hæmoglobinuria. Many cases of hæmaturia appear in the statistics from 1870 onwards, but as it is impossible to say anything further about them, they have been omitted in the following table. Those of "intermittent" hæmaturia have been left in, though no certainty can attach to their interpretation.

We are much indebted to the kindness of Colonel Wilkie, I.M.S., Statistical Office, Simla, for the following table:—

Table to show presence of cases of Hæmoglobinuria in European and Native Troops.

	European troops.		Native troops.		Prisoners.	
	Intermittent hæmaturia.	Hæmoglobinuria.	Intermittent hæmaturia.	Hæmaglobinuria.	Intermittent hæmaturia.	Hæmoglobiduria.
1887..........	2	—	—	—	—	—
1888..........	—	—	—	—	—	—
1889..........	1	—	—	—	—	—
1890..........	—	—	—	—	1	—
1891..........	1	—	—	—	—	—
1892..........	—	—	—	—	—	—
1893..........	1	—	—	—	—	—
1894..........	1	—	—	—	—	—
1895..........	1	—	—	—	—	—
1896..........	2	—	—	—	2	—
1897..........	—	2	—	—	—	—
1898..........	—	—	—	—	—	—
1899..........	—	3	—	1	—	—
1900..........	—	5	—	2	—	—

(1.) Madras.—Rajahmundry Central Jail. Captain Fearnside, I.M.S., in a report on the sickness among the prisoners, writes:—"During the recent epidemic only two cases of hæmoglobinuria or blackwater fever occurred." Elsewhere* Captain Fearnside, writes:—"In 1891 I suffered for 9 months from æstivo-autumnal fever, accompanied in the last stages with blackwater fever."

(2.) Godavery Agency.—The following extract from a letter is self-explanatory:—In September, 1897, I had a very mild attack of blackwater fever in the Bhadrachelam Taluk of the Godavery

* 'Scientific Memoirs by Medical Officers of the Army of India,' Part XII, 1901.

Agency. There are cases not uncommonly in the Jeypore Agency of Vizagapatam, and more than one German missionary up there has suffered badly. . . . He is a very old resident, and has buried many of his brethren, and nursed many cases of blackwater fever."

(3.) Secunderabad.—In Secunderabad, the cantonment of Hyderabad, Southern India, in 1882–83, Lieut.-Colonel King, Sanitary Commissioner of Madras, in a private letter writes:—"I had several cases of the most intense pernicious malarial fever, and, Koch notwithstanding, these cases presented bloody urine before they had had a single dose of quinine."

Assam.

(1.) *Nowgong* (*Salonah Division*).—A tea planter writes:—"There are very few cases of blackwater fever about this district nowadays, but when I came here 23 years ago, and for many years after, there were several cases every year amongst Europeans, and many deaths."

(2.) *Silchar* (*Sylhet*).—*a.* Two cases recorded by Rev. G. G. Crosier, B.S.M.D., in the 'Indian Medical Gazette,' December, 1900.

b. Dr. A. Powell records in the 'Journal of Tropical Medicine' for December, 1898, 11 cases from this region.

c. Dr. B. Seal reports one case from Sylhet.

Bengal Terai.

Dr. B. Seal reports six cases in eight years from the Darjeeling Terai.

Inquiry among the planters and medical officers of the tea estates makes it clear that blackwater fever has been imperfectly well known to the oldest European residents. It has been recognised thus for at least 20 years in this district, but in the early days was known as "jaundice," or "bilious jaundice." There are at present but few European planters resident in the Terai. The Terai had and still has the reputation of being a most deadly fever district.

Bengal Duars.

In this district we have been able to make inquiries personally, and we describe shortly two cases we ourselves saw and two others, the blood films of which were most kindly sent to us by Dr. Cowen, of Nagrakata. Here, again, we were informed by the oldest medical officer, who had resided for 14 years in the district, that the name blackwater fever had only recently been applied to these cases—that previously he simply called them cases of jaundice or bilious fever with jaundice. This corresponds exactly to the information we gathered in British Central Africa, when in the early days of the Protectorate deaths were reported as occurring from severe jaundice with fever.

To what extent blackwater fever prevails in the district it is difficult to determine except by long residence, but we do not think we err in saying that few tea gardens in the Duars have not suffered at some time from blackwater fever.

During the short stay we were able to make there we saw two cases in one week, and four cases occurred within a fortnight. This is a number that was never encountered by us either in British Central Africa or West Africa.

The following two cases were seen by us :—

CASE XVII.—Bengal Duars. Hilda Tea Estate.

Bengalee Babu. Had fever in Assam in 1900. April, 1901. Had fever with dark urine staining his clothes reddish.

23.8.01. A little fever at night.

24.8.01. Fever with ague.

25.8.01. Midday, antifebrin and two quinine pills of four grains each. 8–9 P.M., passed urine like blood.

26.8.01. Midday, temperature 104°. 6 P.M., temperature 104°.

28.8.01. Urine began to clear.

30.8.01. No hæmoglobin in urine. Patient first seen by us. Jaundice. Hiccough. Blood films taken 6 P.M.

31.8.01. Blood films, 8 A.M. Serum very yellow, as seen on slide. Blood rather fluid. Death about midnight.

This case, then, corresponds exactly in two essential points with those we have previously reported, viz., the previous history of "fever" and the previous history of quinine.

The blood examination, as one expected at this late stage of the disease, was negative as regards parasites. The leucocytic values were as follows :—

30.8.01. 6 P.M.

700 leucocytes counted	Large mononuclears ...	15 per cent.
	Small ,, ...	15 ,,
	Polymorphonuclears ...	69 ,,
	Eosinophil cells	1 ,,

31.8.01. 8 A.M.

700 leucocytes counted	Large mononuclears ...	16 per cent.
	Small ,, ...	18·6 ,,
	Polymorphonuclears ...	63·6 ,,
	Eosinophil cells	1·6 ,,

The mononuclear value certainly suggests, but is not conclusive, of malarial infection.

CASE XVIII.—Bengal Duars. Ghatia Tea Estate.

Bengalee bamboo.

26–28.8.01. Slight fever.

29.8.01. Between 7–9 A.M. quinine 1 gramme. Rigor 10 A.M. Passed red urine 12.30 midday. Blood film taken 7 P.M. No parasites.

31.8.01. First seen by us. 11.30 A.M., temperature 100°. Jaundice. Serum yellow. Urine contains no hæmoglobin. Much bile pigment. (This is the first case of blackwater fever in which bile pigment has been found by us in the urine. F. Plehn also mentions the rarity of its occurrence.) Blood films = no parasites, one pigmented leucocyte.

19.0.1. Temperature 98°·6. Blood films = no parasites.

5.9.01. Death occurred.

The evidence of malaria in this case depends on the presence of a pigmented leucocyte, and the following leucocytic counts :—

29.8.01. 7 P.M.

700 leucocytes counted	Large mononuclear ...	20·5 per cent.
	Small " ...	18·5 "
	Polymorphonuclear...	60 "
	Eosinophil	1 "

31.8.01. 11.30 A.M.

1000 leucocytes counted	Large mononuclear ...	17·6 per cent.
	Small " ...	13·8 "
	Polymorphonuclear ...	67·2 "
	Eosinophil	1·3 "

1.9.01.

700 leucocytes counted	Large mononuclear ...	18·2 per cent.
	Small " ...	10·3 "
	Polymorphonuclear...	69·9 "
	Eosinophil	1·6 "

CASE XIX.—J.B.O. Nagrakata. Bengal Duars, India.

Said to have had B.W. in 1896. Went home in 1898. Takes large doses of quinine prophylactically and during attacks of fever. In Calcutta, November, 1901. On his return feeling out of sorts. A good deal of quinine taken.

Quinine History.—December 1, grains 15. December 4, grains 10. December 5, grains 5.

History of Illness.—December 10. Feeling ill. Symptoms of "gastritis."

December 17. 10 A.M. Quinine, grains 10. 4 P.M. Fingers numb. Feels cold. Thinks he is going to have fever. 5 P.M. Passed urine dark colour.

10.30 P.M. "Bad ague." Passed several samples of dark urine.

December 18. Went to work, but felt bad. Urine still not of "right colour."

11.30 A.M. Bad ague. 12.30 NOON. T. 101°·6. Blood films taken.
2 P.M. Brown urine. 4.30 P.M. Blood films taken.
10 P.M. Dark red urine.

December 19. 7 A.M. Urine lighter. Brown.
10.30 A.M. Shivers.
11 A.M. T. 102°. Spleen palpable. Liver tender.
12.30 NOON. Dark red urine. 6 P.M. Blood films.

December 20. 12 NOON. T. 98°·6. Blood films taken.
4 P.M. Dark red urine.
7.15 P.M. Urine normal.

No bile in any specimen of urine. No jaundice observed, but room rather dark. No quinine throughout.

Dr. Cowen, of Nagrakata, most kindly furnished us with the above notes.

Examination of blood.

18.12.01. (NOON). No parasites, no pigment.

Large mononuclear	20·3	per cent.
Small mononuclear	14·3	,,
Polynuclear	64·2	,,
Eosinophil	1·2	,,

18.12.01. 4.30 P.M.

Large mononuclear	18·1	per cent.
Small mononuclear	22·5	,,
Polynuclear	59·7	,,
Eosinophil	0·8	,,

20.12.01.

Large mononuclear	13·3	per cent.
Small mononuclear	24·1	,,
Polynuclear	61·6	,,
Eosinophil	1·0	,,

Case XX.—W., æt. 26. Nagrakata, Bengal Duars arrived in India June 4, 1901. Much fever during the year. December 21, 1900, feeling out of sorts, aching in back and legs. No quinine for 6 weeks.

25.12.01. Quite well in morning. 3 P.M. Felt his hands hot, with fever. Took quinine, grains 10 in a mixture.
6 P.M. Rigors. 7.30 P.M. Vomiting, continuing all night.

26.12.01.

3 A.M. Shivers. Passed dark red urine (albuminous), Fingers numb, bloodless, and stiff.

9 A.M. Quinine, grains 10. Vomited an hour later.

10.30 A.M. Strong rigors. Vomiting, slight jaundice. Dark red urine, one-third albumen.

1 P.M. T. 103°·2. 2 P.M. Dark red urine. 3.45 P.M. Blood films.

6 P.M. T. 103°·9. Spleen extends 4 inches below ribs. Liver 1 inch. Blood films.

27.12.01.

Much jaundice, urine still red. 12 noon. Blood films. 7 P.M. Blood films.

28.12.01.

9 P.M. Urine pale brown.

29.12.01.

Urine pale yellow.

Blood examinations.

26.12.01. 3.45 P.M.

Many typical young single tertians (Romanowsky) with stippling of red cell. One pigmented large mononuclear.

Large mononuclear	23·0 per cent.
Small mononuclear	20·5 ,,
Polynuclear	56·0 ,,
Eosinophil	0·0 ,,

26.12.01. 6 P.M.

A single large parasite only.

Large mononuclear	18·4 per cent.
Small mononuclear	12·4 ,,
Polynuclear	69·2 ,,
Eosinophil	0·0 ,,

27.12.01. No parasites. No pigment.

Large mononuclear	15·75 per cent.
Small mononuclear	24·5 ,,
Polynuclear	59·75 ,,

The blood examination is of extreme interest, as showing how parasites, at first easily found, had in two hours almost completely disappeared, and did not again return in subsequent films.

The cases resembled in every respect those previously seen by us in West Africa and British Central Africa, and there can be no doubt as to the identity of the disease here and in Africa.

Evidently in the Duars blackwater fever is a distinctly common disease, much more so than in India in general. It will be of advantage

to consider what the occurrence of blackwater fever in such intensity in the Duars really signifies, and why it should be more common there than in the rest of India.

If we presume that blackwater fever is in some way dependent upon repeated, or perhaps continuous, malarial infection, the explanation is simple.

The Duars, as shown by the percentage of children infected (endemic index), by the spleen rate, and by the sporozoit rate, is a much more malarious district than the plains of Bengal. In Bengal, the endemic index has been shown by us in the places visited to vary from 0 per cent. to 7 per cent. only, whereas in the Duars it rises to 40 per cent. to 72 per cent. (" The relation of endemicity to ' species ' of anopheles.") We have also seen that one species in particular of *anopheles* is confined to the Duars, and that this species is possibly the cause of the high endemicity, and hence, indirectly, of blackwater fever. We would say, then, that the reason why blackwater fever is so much more prevalent in the Duars than in the rest of India is because in the former we are dealing with a really malarious country comparable with W. Africa, whereas, in the latter, we have a country far less malarial.

The Jeypore Agency—Madras.

This is a hill district with plateaux at about 3000 feet elevation, forming practically a continuation of the Eastern Ghauts. Extending from about the 17th to the 20th parallel N., it lies about 100 miles inland from the coast line at Vizagapatam, Madras. Although we believe no record exists in official reports or medical publications of blackwater fever in this district, yet quite accidentally its existence came to our knowledge, and, further, as we failed on inquiry outside the district to obtain any information as to blackwater fever here, we determined to visit it ourselves.

We found that in the Jeypore district the number of Europeans at any time is exceedingly small. There are about ten German missionaries and an occasional official scattered throughout the district, so that at any time the total number of cases could not be large, but still among these missionaries eight or nine have suffered from blackwater since the establishment of the mission in 1882, and likewise a few cases were known among the officials. So that it is quite clear that in the Jeypore Agency we have a blackwater focus quite as distinct as that of the Duars, though for the reasons stated above the total number of cases is less. We think it possible, too, that other foci may be found in India, as for instance along the Western Ghauts.

There are, further, certain facts which, from our observations of blackwater fever in the Duars and in this district, seem to us of considerable importance.

1. We are much struck on visiting the Duars by the almost exact parallel between the conditions of life there of the European settler and those we had already seen in Africa, and here in Jeypore the conditions were repeated. The Europeans live under conditions in which an almost constant malarial infection can occur, that is, they live in the midst of native huts, and the children have an extraordinarily high malarial index—50 to 86 per cent. (in February), and, as a matter of fact, they constantly suffer from fever and are too constantly taking quinine. This is a condition very different from what prevails elsewhere in India, where the segregation of Europeans in cantonments and comparative freedom from infection is almost general.

2. We had anticipated, as our researches on blackwater had led us to conclude, that blackwater fever is only found in regions of the highest endemicity, that we should find the Jeypore district to be one of high endemicity. This was indeed so: ascending from the plains where—apparently with all the factors requisite for a high endemic index—the endemicity was 0 (Salur), in 15 miles we had reached an index of 50, Sunki (2000 feet) and at Patingi (2800 feet) it had reached 70, and at Bodawalasa (2000 feet) it was 86. We have then to take into account these remarkable variations in endemicity. We have given a parallel instance at Ennur-Madras, where within a distance of 10 miles only, with, so far as we could judge, exact identity of all conditions, there occurred a change in the endemicity from 5 to 55.

We believe that it is only under conditions of high endemicity that blackwater can appear, and at any rate it must be recognised that we cannot explain at present these variations in the malarial endemicity of adjacent districts.

3. In the Jeypore district we found a new anopheles, *A. Jeyporensis*, and *A. Christophersi* the predominant species in the Duars. We have above discussed the relation of species of anopheles to endemicity, and have said that it is at present purely a matter of conjecture whether this factor determines *virulence* of infection with a particular parasite, but this species plays a part in determining the existence of infection we think the facts brought forward by us show.

4. It is noteworthy that here and in the Duars the parasite infection in the native children was a quartan one, and there seems to be, at least in these two instances, an association between quartan infection and high endemicity. In the comparatively low endemic area of the Central provinces the infection was among the native children mainly simple tertian.

5. It is impossible to estimate the influence of climatological factors, but they certainly cannot be disregarded, (1) in their relation to the constitution of the European; (2) in the wider determination of the endemicity (and virulence) of malaria. In this respect, for instance, the Duars cannot be compared with the Punjab, nor the Congo with Algeria.

Conclusions.

1. Blackwater, so far as our present knowledge extends, is, in India, confined to the Duars and Terai (Bengal), the Jeypore Agency (Madras), and to Assam (Sylhet and Nowgong).

2. The endemic index in these regions is extremely high.

3. The endemic index of other portions of India visited by us is comparatively low.

4. The conditions of life, especially the close association with native dwellings—in the blackwater fever districts of India are almost the same as in tropical Africa.

5. The practical outcome of our investigations is that the prophylaxis of blackwater is identical with that of malaria ; and in India, as in Africa, segregation of Europeans from the midst of native infection should play an important part.

"Malaria in an Indian Cantonment (Mian Mir) : an Experimental Application of Anti-malarial Measures.—Preliminary Report." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received February 6, 1902.

Before any practical measures are to be generally adopted against malaria, it is desirable to demonstrate by test operations that these are capable of bringing about the desired result.

Some demonstrations of the utility of anti-malarial measures have already been made :

1. Professor Koch has shown in Stephansort that under the conditions there prevailing malaria could be successfully eliminated by attacking the parasite in its human host through the careful administration of quinine.

2. Major Ross commenced in 1901 extensive operations against malaria in Freetown, Sierra Leone. His methods have been directed in the main to the destruction of *anopheles* (larvæ), and are mainly those of surface drainage and subsidiary measures directed against the breeding of mosquitoes. Already Major Ross is of the opinion that these measures have met with marked success.

3. Several years ago at Accra, Gold Coast, the residences of the officials were removed from Accra town to an unoccupied site about half a mile from any native dwellings, since called Victoriaborg. This is almost the only case we have seen where in Africa a scheme of segregation has been carried out. The result has been to make Victoriaborg reputedly the most healthy European settlement on the West Coast of Africa.

These demonstrations show that malaria has been combated by three very different methods. Apart from personal protection, preventive measures in the tropics appear to be confined to these three methods, namely :—

1. The destruction of the parasite in the human host or quinine administration.
2. The destruction of the carriers of malaria, *anopheles* or mosquito destroying operations.
3. The protection of Europeans in highly malarious countries by segregation.

The probable utility of each of these methods has always to be judged on its adaptability to the particular conditions encountered In many situations all three methods can be applied, in others only one or other is possible.

Amongst a docile or educated population quinine has been shown to succeed. In towns and in dry districts destruction of mosquitoes is likely to be the best method, and when brought about must be of all results the most desirable. In deadly malarial districts and savage countries—indeed, in almost all out stations in the jungle or bush—segregation of Europeans is the only prophylactic measure that is possible. In Africa the conditions of bush and swamp, together with swarming populations, make the diminution of native malaria obviously impossible, and hence the protection of Europeans ought to be the one and only object of first measures.

In India the European has to a large extent protected himself by living in large and isolated bungalows, together with a standard of comfort unknown in Africa. The Europeans in India who are chiefly exposed to danger of infection are soldiers in cantonments, where, as we shall see, several conditions conspire to render these centres of malaria.

In India also the high state of sanitary administration makes it likely that, on the whole, mosquito destruction will be the preventive measure most generally applicable. But in India, also in certain districts as in the Bengal Duars, the conditions approximate closely to those of an African out-station, and here, too, segregation will be the first measure of protection.

The Choice of a Cantonment.

While desiring, then, to demonstrate practically the utility of all anti-malarial measures, we wished especially to turn our chief attention to the destruction of anopheles (larvæ).

We selected a military cantonment with an exceedingly high malarial rate, and which was at the same time very dry. It was obviously inexpedient to select a site where there was much swamp, as the

drainage or filling up of this would necessarily be a matter of time, and probably considerable expense. These conditions, we thought, were furnished by Mian Mir cantonment in the Punjab. We shall see later, however, that although in a district which is so dry as almost to deserve the appellation "desert," yet there is abundant water for the breeding of anopheles.

The Conditions found at Mian Mir.

Mian Mir cantonment is situated on an extensive and level plain of alluvium, and throughout the greater part of the year is totally free from water except that of artificial supplies (irrigation channels and deep wells). The arid, sun-scorched, dust-begrimed appearance of the land is very striking, yet anopheles are very plentiful, and *anopheles'* larvæ are nearly everywhere present in the waters of the irrigation system.

Breeding Places of Anopheles.

A main canal enters the cantonment, and from this distributing channels convey water to gardens, &c., within the cantonment and in some instances to agricultural areas without. The flow in these channels is practically constant, and water is distributed as occasion demands over different pieces of ground. Here and there a shallow pool may be found, the overflow of some channel, but such pools are not many. The breeding places of *anopheles* in Mian Mir are:—

1. The medium sized canals.
2. The small distributing channels.
3. A few shallow pools and small cement tanks.
4. Earthenware fire pots, kerosine tins, and horse troughs.

The water which is distributed by means of Persian wheels over the land is negligible as a breeding ground, as the water is rapidly absorbed into the dry soil, and we have rarely detected larvæ in such water.

In the larger channels (4–6 feet wide) noted above, the flow of water is about 1·5 feet per second. In the open water of these canals larvæ do not occur. There is, however, very generally a fringe of grass or weed projecting inwards from the banks. In the shelter of this fringe, where the flow of water is impeded, anopheles larvæ are very frequently found.

In the large canals such as that bringing the water into Mian Mir, full-grown larvæ are rarely found, except where the flow of water is checked by one of the many bridges which cross the canal. There are, however, throughout the whole length many minute larvæ always present. This condition is so uniform that the conclusion is inevitable

that the eggs and young larvæ are carried down stream to develope among the grass edging the comparatively still water near the bridges.

In the small channels the growth of vegetation is often much ranker and in some water plants exist. In such channels larvæ of all sizes are generally abundant, but especially so near bazaars.

Overflow pools are generally shallow muddy puddles. If near a bazaar or native huts they generally contain many larvæ.

In the large tanks in Mian Mir we have not found larvæ. In a small cement cistern *anopheles*' larvæ were found in large numbers, as also in some horse troughs.

Both in earthenware fire pots and in paraffin tins we have found *anopheles*' larvæ.

The Species of Anopheles in Mian Mir.

Following upon our work in Bengal, we set about determining what species of *anopheles* existed in Mian Mir and what was the nature of the breeding places of each.

The following species were found by us :—

1. *A. Rossii* (Giles). The commonest mosquito.
2. *A. culicifacies* (Liston). Very common.
3. *A. Stephensi* (Liston). Not common.
4. *A. pulcherrimus* (Malaria Commission). A few adult insects only.
5. *A. Jamesii* (Liston). Rare.
6. *A. Sinensis s. sp. Nigerrimus* (Theobald). Larvæ only.

In a large series of observations the larvæ taken from the canals were all those of *A. culicifacies*. In some of the more weed-grown canals the larvæ of *A. Sinensis* also occurred. The larvæ of *A. Rossii* and *A. Stephensi* were never found by us in the canals in Mian Mir. In a slow flowing weedy canal at Meerut *A. Rossii* was present amidst innumerable *A. culicifacies*.

In the shallow muddy overflow puddles the larvæ were invariably those of *A. Rossii*. Only where the overflow was extensive and contained much weed growth were the larvæ also of *A. Jamesii* and *A. Sinensis* found.

Larvæ taken from paraffin tins and earthenware pots were always those of *A. Stephensi*.

A. pulcherrimus, which is a rare species, has not yet been found breeding by us.

We have then the same remarkable distinction between the breeding places of the species in Mian Mir that we have previously drawn attention to in Bengal.

In September and October the winged insects of *A. Rossii* were extremely abundant in nearly all the native bazaars, and in some

saddle rooms near the cavalry stables. In the barracks a few only were to be caught with difficulty.

The number of *A. culicifacies* varied considerably in the different bazaars. Though in some cases they were very abundant in the regimental bazaars, yet one or two specimens only were caught by us resting in the daytime in the barracks.

In the case of *A. culicifacies* a direct relationship seemed to hold good between the proximity of irrigation channels and the number of adult insects in the bazaar.

With *A. Rossii*, however, it was extremely difficult to trace a very close connection between the occurrence of the adult insects and the presence of breeding places. This species swarmed in nearly every native quarter, though breeding places in several cases could not be found, whilst in others the small number of larvæ seemed quite out of proportion to the large number of adult insects. Near some bazaars shallow muddy pools existed containing many thousands of larvæ. The breeding places of *A. Rossii* appear to be very evanescent in nature, consisting of shallow pools which for a week or two breed many thousands of mosquitoes, and then disappear, leaving little trace of their existence.

In November a great diminution of *A. Rossii* had taken place in many of the situations where they had a month ago swarmed.

Human Malaria in Mian Mir.

In or close to cantonments in India there generally are small native villages known as "regimental bazaars."

In Mian Mir there are several of these. They form a convenient test of the endemic index of the cantonment.

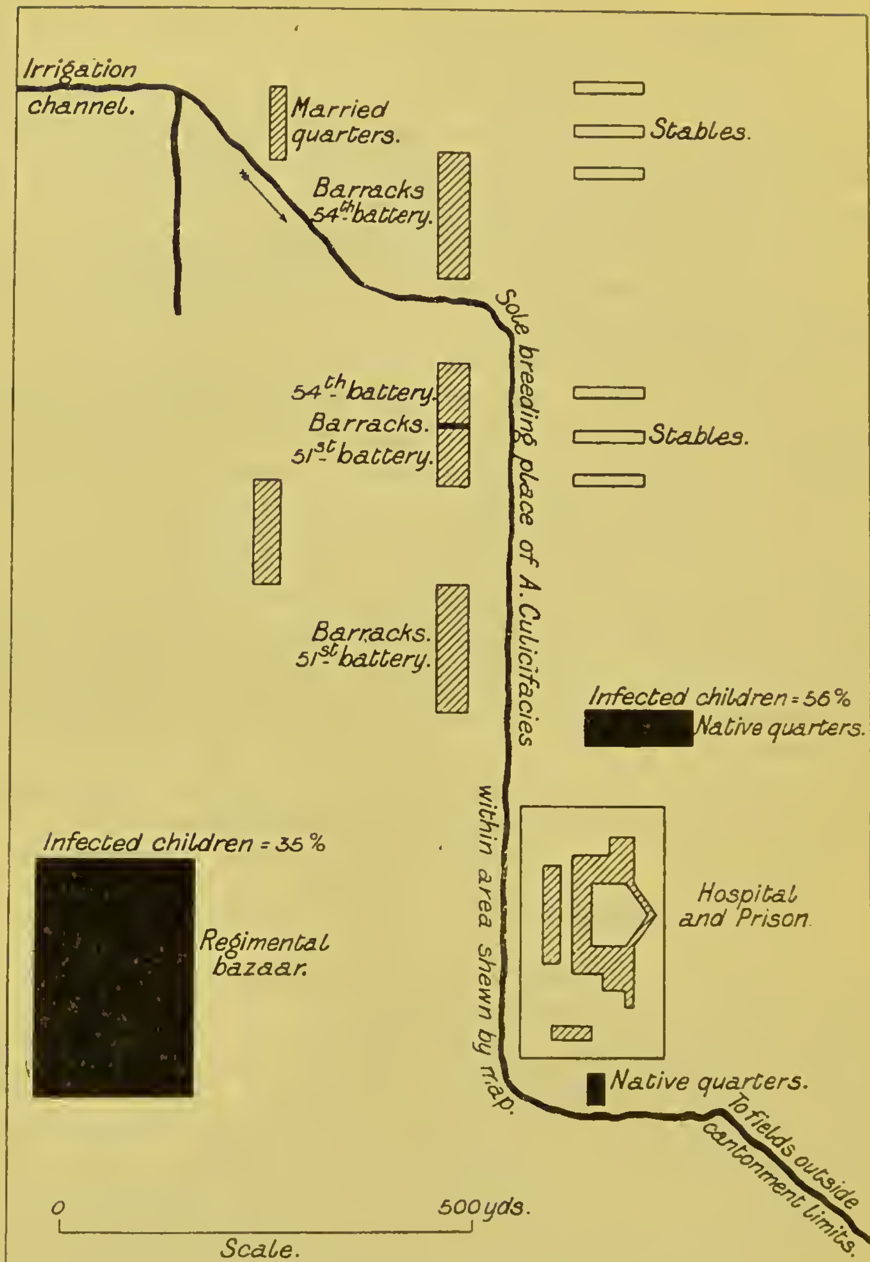
Some variations in the percentage of children infected occurred more or less dependent on the facilities for the breeding of *A. culicifacies.* Although we were unable to find (in November) in some bazaars many *anopheles*, either *A. Rossii* or *A. culicifacies*, yet the malarial index was still high. This may simply have been that *anopheles* had disappeared shortly before, as might easily be the case where *A. culicifacies* is concerned, from the cleaning of a single ditch.

The results of the examination of the children of different bazaars shows a correspondence between the proximity of ditches and the malarial index.

Table I.

That these bazaars constitute a large source of infection for the troops is undoubted. They are as it were great central depôts of anopheles and malarial parasites.

One of the Royal Artillery barracks in Mian Mir has two such native quarters close at hand (see plan).



Plan of Royal Artillery lines, showing conditions relating to the spread of malaria. Native quarters shown in solid black.

Infection among the European Troops.

A number of men of the 54th and 51st batteries of the Royal Artillery at Mian Mir were examined towards the end of November, when presumably the fever season was not at its height.

One-half of the entire strength of the 54th, and every fourth man of the 51st taken in the order in which they slept in barracks was examined.

The result of the examination was unexpected, and is shown in the following table :—

	Number of men examined.	Percentage of infection.
54th battery	52	17·3
51st battery	34	29·4

The hospital statistics of returns for malaria are obviously inadequate to express the real extent to which malaria prevails among the European troops. The number of cases admitted to hospital must be to a large extent only a secondary effect depending upon the presence of a hitherto unsuspected widespread "latent" infection, equal in the Royal Artillery lines in Mian Mir to nearly a third of the full strength of a battery.

Methods by which Malaria under such circumstances may best be Combated.

1. *The Test of the Reduction of Malaria.*—In any experiment which has for its object the demonstration of the utility of practical measures, careful consideration must be given to the tests of success to be employed.

The general opinion of the inhabitants of a station is far too vague to be of much value. We can, however, show that destructive measures have been successful by the following means:—

(1.) It can be made evident that though previously at the same time of year larvæ were found readily, yet in the year of the experiment they were not so abundant. If the measures adopted are successful, there ought to be no doubt as to this point.

An estimate of the ease with which larvæ are caught in the same waters in the year previous to and subsequent to destructive measures should show a well-marked and easily recognisable diminution in the latter year.

(2.) While *anopheles* can be caught in houses, probably they are abundant. The ease with which they are found depends very much upon the facilities one has for detecting them—such as the presence of rooms with low, sooty ceilings, unoccupied houses, sheds, and out-houses. In a given bazaar, however, it is possible for one who has regularly collected *anopheles* there to say with certainty that they are more or less abundant. If next year there is a well-marked decrease in one or other of the species of *anopheles* we shall be in a position to determine this fact with certainty.

(3.) Most difficult of all may be the demonstration that there is a real improvement in the health of the station. We hope, however, that by this test also the effect of a vigorous attempt to prevent *anopheles* breeding may be shown in a diminution of the following:—

1. Admissions for "ague" and "remittent fever" to the hospitals.
2. The percentage of infection among the troops.
3. The endemic index of the regimental bazaars.

In the case of hospital statistics we are dealing with an element of uncertainty, as relapses and even other fevers may be entered as fresh infections of malaria.

In order to see what proportion of cases of "ague" were really malaria, a number of men admitted to hospital as ague cases were examined.

Of these, 40 per cent. showed parasites. As many of the men had quinine before admission, we may consider that the increase in admissions for fever from June to November is really due to malaria.

It ought, then, to be possible to show *a diminished statistical return for fever and ague* in these months.

The percentage of infection among the troops is a more reliable index of the amount of malaria than the hospital returns. The percentage in the men of the Royal Artillery batteries we have seen to be 17·3 per cent. to 29·4 per cent. at the end of November, when the number of admissions for malaria are less than in the height of the fever season. If operations against malaria are successful, this high percentage of infected men ought to be much reduced.

Finally, we have a very accurate test in the endemic index (parasite rate) among the native children of the various regimental bazaars. If these show a well-marked reduction, we can fairly conclude that measures directed against *anopheles* in Mian Mir have been successful.

2. *The Prevention of Malaria in Mian Mir.*—In an accompanying report we show that in Mian Mir while *A. culicifacies* was actively carrying malaria, *A. Rossii* did not appear to be doing so.

In the bazaars the proximity to ditches and the numbers of Culicifacies seemed to influence the amount of infection, whereas the number of *A. Rossii* did not seem to have any relation to the fever rate.

Although therefore it would, in the present state of our knowledge, be advisable to keep a sharp look out against the shallow muddy pools in which *A. Rossii* breed, yet in the main our attention should be turned to the prevention of the breeding of *A. culicifacies.*

The extermination of *A. culicifacies* practically consists in some effective way of preventing *anopheles* breeding in the irrigation canals, and especially in the small irrigation channels.

It has been seen that the grassy edges give the shelter and reduced rate of flow necessary to the development of the larvæ. Some experiments were therefore made to show whether the cleaning of these edges, so that an even earth surface was given to the bank, had the effect of doing away with the larvæ.

Experiment 1.—A length of the main canal in which we had

previously detected small larvæ along the whole length was cleaned. On a second visit no larvæ were found until a portion left uncleaned was reached, when many small larvæ were present. This freedom from larvæ continued many weeks.

Experiment 2.—A channel lying close beside a regimental bazaar was cleared of all grass and weed. No larvæ were ever afterwards detected here. A canal on the other side of the bazaar, but further removed, was left in its original uncleaned condition. Here larvæ of all sizes were very abundant.

The cleaning of canals, thereby removing weed and promoting flow, therefore very much reduces, if it does not altogether prevent, the development of larvæ.

Some of the canals and channels within the cantonment are used for the supply of water to gardens; others, however, supply agricultural tracts within and even outside the cantonment.

As an example we may note an irrigation channel which passes through the Royal Artillery lines past the hospital and prison to supply some fields beyond. In this channel are many larvæ of *A. culicifacies*, and as it is almost the only source of larvæ within this area, it may be considered the cause that maintains most of the malaria among the Royal Artillery at Mian Mir.

There can be no doubt that this channel, less than a yard wide, should either be done away with, or that it should be made into a well-built brick aqueduct.

Could all irrigation channels within the limits of Mian Mir be made of brick it would enormously improve the health of the cantonment. Some at least of the channels, namely, such a one as that described, which passes within a stone's throw of three barracks, married quarters, a hospital, and a prison, ought to be done away with or made permanently unfit for the breeding of *anopheles*.

In our present experiment we hope, chiefly by the constant cleaning of canals and channels, maintained for many months, to show a definite improvement in the health of Mian Mir.

An experiment on a small scale was undertaken by cleaning the ditches around a small regimental bazaar to demonstrate a reduction of the winged insects. Unfortunately, however, the experiment, though successful, is not conclusive, as *anopheles* by this time were becoming less in other parts of the cantonment, presumably owing to the onset of the cold weather.

Although the demonstration of the possibility of prevention of the breeding of *anopheles* is the main object we have in view, yet other means of prophylaxis are so evidently applicable, that in one or more cases we shall endeavour also to put them in action.

1. The regimental bazaars have already been mentioned. In the case of the Royal Artillery barracks a collection of Syce huts is within

100 yards of the European lines. Such a state of affairs can only be looked upon as dangerous in the extreme. Even though the larger regimental bazaars cannot at once be done away with, all such small native quarters as the above-mentioned Syce lines ought to be removed without hesitation. In the instance noted there is nothing to prevent the quarter being removed half a mile or more out on to the Maidan.

2. Attention has also been called to the high degree of infection in men supposed to be in health and performing their regular duties. As in nearly every case the parasite encountered was the benign tertian, it is impossible to believe that the quinine issued at present is actually taken by the men. So far as we have been able to gather, quinine administration in institutions or to troops is only likely to be effective if quinine parades are instituted and each man made to swallow his dose in the presence of the medical officer. An active quinine administration under personal supervision would, we feel sure, enormously reduce the large latent infection found by us in the men of the Royal Artillery in Mian Mir.

"Brief Summary of Conclusions arrived at in the Previous Papers." By J. W. W. STEPHENS, M.D. Cantab., and Lieut. S. R. CHRISTOPHERS, I.M.S., M.B. Vict.

The Malarial Infection of Europeans—Prophylaxis.

1. In tropical Africa (but perhaps to a less extent in certain regions of India) there is a widespread infection among the native children (under fifteen years of age). Above this age there is a marked immunity.

2. This infection through natives is the essential cause of European malaria, so much so that infection from one European to another may be neglected as a factor in the spread of the disease.

3. The chief source of infected *anopheles* is native huts. In fact, the true distribution of *anopheles* (at least during the dry season) is identical with that of native huts.

4. Segregation offers the most practical and immediately effective means of diminishing the death roll among Europeans.

5. Efficient protection to Europeans would be afforded by a segregation of a quarter of a mile from native huts, and in many instances by a few hundred yards only. Half a mile would, we believe, afford absolute protection.

6. Segregation in towns also is practicable. It exists at Accra (Gold Coast), and is moreover the condition met with throughout India, viz., European cantonment and native bazaar.

7. The diminution of native malaria, as a whole, is an extremely difficult and costly task. The most efficient means to accomplish this end is drainage.

Blackwater Fever—Nature—Prophylaxis.

8. Cases of malaria may occur where parasites are absent in the peripheral circulation. In such cases there are two subsidiary means of diagnosis:—(1) The presence of pigmented leucocytes. (2) An increase in the percentage of the large mono-nuclear leucocytes.

9. In blackwater fever parasites are generally absent; but by the use of these subsidiary tests proof of its malarial origin may still be obtained.

10. Blackwater fever is not due to a special parasite; but, in spite of the frequent absence of parasites, is malarial in origin. And, moreover, it is not infrequently in direct association with a preceding infection. For

11. In the only case of blackwater fever seen by us *before* the onset of the hæmoglobinuria, parasites were present in abundance. After the hæmoglobinuria they rapidly disappeared. So far as we know, no exception to this fact has been observed.

12. Further, blackwater fever is most commonly induced by quinine, not necessarily in a large dose.

13. Quinine is dangerous solely when it is inefficiently administered, *i.e.*, in those who, in spite of taking quinine, suffer from constant malarial attacks.

14. Blackwater fever is as common in the Bengal Duars as in any region of Africa visited by us. It is also present in the Madras Presidency (Jeypore) and in Assam.

15. Blackwater fever only exists in regions of *intense* malarial endemicity.

16. The prophylaxis of blackwater fever is identical with that of malaria, viz., efficient segregation from the ever-present source of native infection.

Malarial Endemicity.

17. The endemic index or endemicity of a village or district may be defined as the percentage of children (under ten) carrying parasites in their blood.

18. In *any particular district* the endemicity varies directly with the proximity of breeding grounds of anopheles.

19. In villages with no breeding grounds nearer than half a mile, in the dry season the endemic index may be as low as 5 per cent., and not infrequently 0 per cent.

20. On the other hand, the presence of *anopheles* in abundance is in itself not sufficient to cause a high endemic index.

21. Myriads of anopheles may occur in villages, and yet the endemic index be 0, even if the species of *anopheles* present is one that carries malaria elsewhere. Three such villages were found by us in India. (Paludismus sine malaria.)

22. There are unknown factors—regional factors—which determine why one district has a high endemic index and another a low one.

The Part played by Species of Anopheles in determining Intensity of Malaria.

23. Endemic malaria is in probability *in part* determined by the species of *anopheles* present, for whereas in Calcutta, where *A. Rossii* abounds, the endemic index is 0, in the Bengal Duars, where *A. Christophersi* is the principal *anopheles*, the endemic index is 72.

24. That species is a factor, is, we consider, shown by the result of our dissections of two species of *anopheles* caught in the same huts at the same time. Thus:

1. Mian Mir.

	Anopheles dissected.	Number with sporozoits.	Percentage sporozoits.
A. culicifacies	259	12	4·6
A. Rossii	496	0	0

2. Ennur.

A. culicifacies	69	6	8·6
A. Rossii	364	0	0

25. Although we believe on these grounds and others of a more general character that *A. Rossii* does not carry malaria in nature, yet experimentally it does, as do all other species used by us.

26. Other anopheles, viz., the "wild" or "non-foveal" species, *e.g.*, *A. Barbirostris*, probably also do not carry malaria in nature.

27. The distribution of the particular varieties of malaria parasite in India is peculiar; thus, in the Duars and Jeypore (Madras) the infection among the natives was almost exclusively quartan, while in the Punjab quartan was rare.

28. *A. culicifacies* was the only *anopheles* in which we succeeded in developing quartan sporozoits, but the number of experiments was not large enough to say that the other *anopheles* used did not carry quartan.

Habits of Anopheles—Classification—Malarial Cachexia, &c.

29. Marked peculiarities are shown by different species of *anopheles* in selecting breeding places. Thus, the larvæ of *A. Rossii* are found in shallow dirty puddles, those of *A. Barbirostris* never are, but only in weedy lakes. *A. Christophersi*, again, breeds in streams, but never in shallow pools. *A. Stephensi* not infrequently breeds in tins, and each group of *anopheles* has characteristic but different breeding grounds.

30. The flight of *anopheles may* extend to a quarter of a mile from breeding grounds, but rarely to half a mile.

31. Indian anopheles admit of a natural classification based upon the larval characters and those of the egg. In the different groups there are well-marked differences.

32. The egg of *A. Turkhudi* is remarkably aberrant in type.

33. In the larva the antennal hair, clypeal hairs, and palmate hairs are of specific importance.

34. Fertilisation of the female is not essential for the *anopheles* to develop parasites (zygotes).

35. In the glands of certain species of Culex, bodies resembling sporozoits were found by us. Their nature remains unelucidated.

36. Sporozoits were shown by us to be capable of agglutination like bacteria. We are unable to say whether any specific relation exists to the serum of a malaria patient.

37. The so-called "malarial cachexia and enlarged spleen" of India (Calcutta) has no immediate connection with an active parasite infection.

Note.—The following is a complete list of reports sent in by us :—

1. The Malarial and Blackwater Fevers of British Central Africa. (December 10, 1899.)
2. Distribution of Anopheles in Sierra Leone (including a Report on Blackwater Fever). (April 5, 1900.)
3. The Native as the Prime Agent in the Malarial Infection of Europeans. (May 17, 1900.)
4. Note on Certain Bodies found in the Glands of two Species of Culex. (May 17, 1900.)
5. The Malaria of Expeditionary Forces and the Means of its Prevention. (May 17, 1900.)
6. The Agglutination of Sporozoits (Preliminary Note). (July 14, 1900.)
7. The Malarial Infection of Native Children. (October 1, 1900.)
8. On the Destruction of Anopheles in Lagos. (October 1, 1900.)
9. Note on Malarial Fever contracted on Railways. (October 1, 1900.)
10. The Segregation of Europeans. (October 1, 1900.)
11. The Anatomy and Histology of the Adult Female Mosquito. (August 13, 1900.)
12. The proposed site for European Residences in the Freetown Hills. (November 26, 1900.)

13. The increase in the number of large Mononuclear Leucocytes as a Diagnostic Sign of Malaria. (November 26, 1900.)
14. Malarial Fever without Parasites in the Peripheral Blood. (November 26, 1900.)
15. The Tonicity of the Blood in Malaria and Blackwater Fever. (November 26, 1900.)
16. Blackwater Fever. Cases IX to XVI. Summary and Conclusions. (November 26, 1900.)
17. The Relation of Malarial Endemicity to Species of *Anopheles*. (October, 1901.)
18. Some Points in the Biology of the Species of *Anopheles* found in Bengal. (October, 1901.)
19. The Relation between Enlarged Spleen and Parasite Infection. (October, 1901.)
20. The Classification of Indian *Anopheles* into Natural Groups. (February 6, 1902.)
21. The Relation of Species of *Anopheles* to Malarial Endemicity. (February 6, 1902.)
22. The Relation of Species of *Anopheles* to Malarial Endemicity (Further Report). (April 15, 1902.)
23. An Investigation into the Factors which determine Malarial Endemicity. (April 25, 1902.)
24. Note on Bodies in Salivary Glands of *Anopheles*, &c. (April 25, 1902.)
25. Occurrence of Blackwater Fever in India. (October, 1901.)
26. Malaria in an Indian Cantonment (Mian Mir) : an Experimental Application of Anti-malarial Measures. Preliminary Report.

REPORT BY CAPT. S. P. JAMES, I.M.S.

"A Report of the Anti-malarial Operations at Mian Mir (1901—1902)." By Captain S. P. James, M.B. (Lond.), I.M.S.

Part I.—General.

The operations to be described in this report were initiated with the object of demonstrating in an experimental way that malarial fevers can be prevented by practical measures based on the discovery of the mosquito cycle of the malarial parasite.

Choice of a Station.

Our original object was chiefly to test the efficacy of mosquito destruction in the prevention of malaria, and it was necessary, therefore, to select a station in which it seemed probable that a marked reduction in the number of mosquitoes could be effected. It was also desirable to choose a very malarious station, in order that the results of our experiments might be more evident. From both these points of view the cantonment of Mian Mir appeared to be suitable, for as regards the possibility of reducing *anopheles*, it was evident that, the rainfall being a small one during the greater part of the year, breeding places could only exist in connection with irrigation works; and as regards the prevalence of malaria, this cantonment is recognised as being one of the most unhealthy in the Punjab.

Situation and General Account of Mian Mir.

Mian Mir cantonment is situated on a level plain 6 miles to the south-east of Lahore city, and about 4 miles to the east of the civil station. The locality was selected in 1851–52, when it was decided to abandon the former cantonments at Anarkali (in Lahore) on account of their unhealthiness. The new cantonment was at that time a treeless desert, but many trees have since been planted, and in all parts to which irrigation extends good gardens and grass lands have been laid out. The ordinary garrison of the cantonment is made up as follows:—

2 batteries of Royal Field Artillery.
1 regiment of British Infantry.
1 regiment of Punjab Pioneers.
1 regiment of Native Infantry.
1 regiment of Bengal Cavalry.

The total number of officers and men of these regiments averages about 3900, and in connection with the ambulance and transport establishments there are in addition about 600 native followers.

The arrangement of the cantonment is as follows :—On the extreme north is the bazaar of the British infantry, and to the south-west of it is their hospital. Then follow to the south the lines of the European infantry, with the officers' quarters on the east, and the Catholic chapel and rifle range beyond; then to the east by south of these again is the quarter guard, the magazine, and another set of officers' quarters to the east. Then follow, to the south, the racket court and executive engineer's office, and to the east of these the lines of the native infantry, and again to the south of these the Royal Artillery lines, and at the extreme south the lines of the native cavalry.

Rainfall and Climate.

The average annual rainfall in Mian Mir is about 20 inches. The following table, giving the average rainfall for each month of the years 1868–1892, shows the distribution of the rainfall throughout the year :—

Month.	Average rainfall in inches.
January	0·6
February	1·1
March	0·6
April	0·4
May	0·8
June	1·5
July	5·7
August	4·6
September	2·0
October	0·3
November	0·1
December	0·5

The greatest amount of rain falls, therefore, from June to September, the chief fall being in July.

The hottest month of the year is June, the temperature in a carefully shut house in that month varying from 96–106° F., and unless rain comes, the heat lasts on into July.

The hot weather indicates its approach in April, but indoors it is fairly comfortable until May. Then the air becomes very dry, and hot burning winds commence. The nights are warm, but not troublesome during May, and both April and May are comparatively healthy months for Europeans. In June the heat increases considerably, and hot winds are prevalent. Early in July there is generally a burst of the monsoon rain, but owing to its short duration its cooling effect only lasts for a few days, and unless more rain comes, the great heat begins again, and is rendered worse by the increased moisture of the air. Throughout July and August the nights are very hot, and in the

latter month searching hot breezes sometimes spring up, which are especially trying in Mian Mir. In September the nights begin to be less hot, and from September 15 the days, also, are distinctly cooler. Early in October it is quite cool out of doors, and by the middle of the month the weather becomes very pleasant. This, however, is the month when malarial fevers are most prevalent. November and December days are bright and clear, and the nights cold. Rain sometimes falls before the end of December. In January and February early morning frosts are noticeable. March is very variable, but generally pleasant, and in April the hot weather begins to make itself felt again.

Barracks of the Troops.

The European troops are housed in lofty one-storied stone buildings provided with a wide verandah, and raised some feet off the ground. In the hot weather punkahs are provided by day and night.

Water Supply.

The European troops have a pipe water supply for drinking purposes. The water supply of the native troops is from wells, of which there are a very large number in the cantonment.

Surface Drainage.

One of the worst features of Mian Mir as a cantonment is the fact that the plain on which it is situated is so level that very little of the surface water can drain away. The whole cantonment is interlaced with brickwork surface drains, but in none of these is there any sufficient fall, and the majority end abruptly on the level plain in the middle of the cantonment. In the construction of these storm-water drains there appears to have been no definite object, and they are indeed of more harm than good, for whenever a slight shower of rain falls they become full of water, which remains in them until dried up by the sun. For this reason, they form during the rainy season prolific breeding places of *anopheles* mosquitoes.

Character of the Soil.

The surface layer consists for the most part of very dry, finely-powdered mud and sand, which, during the fierce winds of the hot weather, is blown about in clouds of dust. Beneath this superficial layer the soil consists for the most part of clay and *kanker* (a soil used for making roads, and which on treatment with water becomes hard and impervious).

In consequence of the soil being for the most part impervious to

water, after one or two hours' rain the appearance of the cantonment is changed from that of a dry arid plain to that of a district in flood. Broad expanses of water often a quarter of a mile in extent cover the plain on every hand, and the inhabitants of the followers' huts on some of the comparatively low-lying parts are literally flooded out. The majority of these large expanses of water dry up in the hot sun in three or four days, but numerous small pools are left which, lasting for a week or ten days, form excellent breeding places of *anopheles.*

Irrigation Works.

In the absence of irrigation Mian Mir would, during the greater part of the year, be little better than an arid desert. A branch of the main irrigation canal enters the cantonment, and from this numerous shallow channels (irrigation watercourses or "cuts") convey water to all the gardens, grass land, and crops in the cantonment. The water is drawn up from these channels by means of Persian wheels ("*Jhalars*") and distributed over the land in shallow ditches. No crops requiring continuous irrigation are grown in the cantonment, and the plan usually adopted is to water a certain area of land one day and another the next, so that the water has time to soak into the ground or dry up before the next supply is given. In the garden portions the plan is usually for the Persian wheels to work about three hours daily, and all the water given has generally soaked into the ground by the same evening.

At certain times of the year the supply of water is frequently shut off for ten days or more at a time. This is shown in the following table :—

Table showing the Number of Days of each Month during which Irrigation Water was supplied to Mian Mir Cantonment for some years between 1892 and 1901.

	1892.	1893.	1897.	1898.	1899.	1900.	1901.
January ...	16	3	11	7	10	0	3
February...	13	0	4	7	19	9	0
March.....	23	4	22	21	26	22	27
April......	24	22	28	30	25	27	27
May	26	21	31	31	31	31	30
June......	28	25	29	30	30	21	23
July.......	13	28	31	29	31	28	28
August	14	31	31	31	31	14	21
September..	22	22	30	30	21	19	30
October....	30	30	23	21	14	28	20
November..	30	0	20	20	10	21	16
December..	31	0	18	20	14	15	7

Before any anti-malarial operations in a place can be carried out with any hope of success, it is necessary to have exact knowledge of the real prevalence of malaria in the place and of the conditions on which this prevalence depends. Our previous work had shown that the general opinion of the inhabitants of a place as to its healthiness or otherwise, and even the statistics of admissions into hospitals for "fevers," are of little value as an indication of the prevalence of malaria and the danger of infection.

Before commencing operations in Mian Mir therefore we spent some time in a study of the prevalence of malaria there and the conditions which determine it.

The Prevalence of Malaria in Mian Mir and the Conditions determining it.

As will be seen from the following table, Mian Mir is one of the most unhealthy cantonments in this part of India :—

Table showing the Average Annual Admission Rate per 1000 of Average Strength for "Ague" among European Troops for the Years 1896—1900 inclusive in some Stations of the Punjab and United Provinces.

Mian Mir	663·0	Agra	259·0
Sialkot	271·0	Delhi	1145·6
Rawalpindi	289·0	Meerut	477·2
Amritzar	445·6	Fatehgarh	464·4
Jullundur	260·9	Cawnpore	294·5
Ferozepore	760·6	Lucknow	204·3
Umballa	289·8	Fyzabad	231·2
Jhansi	355·7	Fort Allahabad	400·6
Benares	273·2		

The number of admissions per 1000 for malarial fevers among European troops at Mian Mir, during the year 1901, is shown in the following table :—

European Troops at Mian Mir. Malarial Fevers ("Ague" and "Remittent"). Admitted per 1000.

1901.		1901.	
January	152·0	July	63·5
February	68·3	August	126·9
March	69·5	September	153·1
April	63·4	October	219·8
May	159·4	November	143·3
June	141·4	December	62·8

From this table it would appear that malarial fevers are prevalent in Mian Mir throughout the year. This is not, however, the case, and a large number of the cases recorded in the hospital returns are doubtless due to relapses.

It is certain also that other diseases than malaria are often returned under the term "ague." In order to ascertain what proportion of the admissions for "ague" were really due to malaria, a number of men admitted for this disease were examined in October, 1901, by Dr. Christophers, and in 40 per cent. of these, malarial parasites were found. In the same way I examined a number of men admitted or "detained" for ague during September, 1902, before any quinine had been administered to them, and found malarial parasites in 45 per cent. of the cases examined. During this month also, through the courtesy of Major Gordon Hall, R.A.M.C., no quinine was administered as medicine to a number of cases in which I had not found parasites. All of them recovered in from one to three days without any quinine treatment, and from this fact and the fact that several examinations of each case failed to show the presence of parasites, I conclude that these cases of fever were not due to malaria, though usually entered as such in the returns. The charts of some of these cases are given in an appendix to this report (see Appendix A).

In considering hospital statistics, however, if we regard the ratio of error to be about the same each year, we may derive useful *comparative* information regarding the prevalence of fevers in different years and at different seasons. For this reason the following tables are given here (p. 33).

It will be seen from these tables that the largest number of admissions for malarial fevers occurs, as a rule, between August and November.

A more reliable method of estimating the prevalence of malarial fevers and the liability to infection is given by an examination of young children, in order to find the percentage infected with malarial parasites. Drs. Stephens and Christophers have added to this method the estimation of the percentage of *anopheles* mosquitoes infected with sporozoites in the salivary glands, as indicating more accurately the actual danger of infection. Every cantonment in India has a number of followers' lines and native bazaars attached to it, and the examination of the children in these lines and bazaars affords a ready means of estimating accurately the prevalence of malaria and the liability to infection.

European Troops at Mian Mir. Malarial Fevers (Ague and Remittent). Admitted per 1000.

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892......	56·8	41·4	46·7	40·3	55·6	62·2	57·3	149·3	110·9	165·9	196·7	123·5
1893......	54·2	35·0	55·4	41·2	74·6	109·7	156·9	142·6	81·0	134·3	102·4	88·3
1894......	49·1	14·1	7·4	3·9	56·1	58·1	85·3	146·0	203·9	332·5	223·5	193·0
1895......	118·2	84·1	106·3	189·1	152·9	174·9	143·9	127·6	125·0	148·0	166·4	32·7
1896......	12·1	3·9	6·7	14·1	10·8	43·5	33·7	9·6	47·2	87·5	37·0	28·9
1897......	10·6	17·2	23·5	12·5	14·9	15·2	23·5	19·8	106·0	58·4	284·8	186·9
1898......	84·5	33·6	30·4	45·0	68·9	5·2	24·0	10·8	88·8	209·1	126·0	97·8
1899......	33·0	37·6	38·6	36·8	80·7	56·7	50·8	29·8	58·2	49·9	18·0	6·6
1900......	15·4	9·0	21·7	24·5	11·1	16·2	9·3	29·7	138·8	356·4	261·3	229·1
1901......	152·0	68·3	69·5	63·4	159·4	141·4	63·5	126·9	153·1	219·8	134·3	62·8

Native Troops at Mian Mir. Malarial Fevers. Admitted per 1000.

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892......	25·7	12·6	17·1	26·0	33·0	14·2	3·6	33·3	52·2	88·0	54·0	16·1
1893......	6·8	4·9	4·2	6·2	8·2	7·3	15·2	46·5	15·2	27·9	19·9	34·3
1894......	28·3	21·4	6·3	16·8	14·2	8·7	25·4	47·8	91·7	136·6	40·2	30·9
1895......	4·6	1·3	4·0	13·6	23·0	7·7	28·7	37·5	120·9	146·3	21·2	19·5
1896......	8·5	5·2	7·6	4·2	4·3	8·2	18·2	12·9	13·7	13·1	13·8	4·4
1897......	3·5	1·0	2·7	5·8	10·6	10·4	11·1	20·3	73·5	119·0	141·2	48·3
1898......	16·2	9·0	11·1	13·9	27·0	35·9	22·6	113·6	100·5	219·0	160·3	42·7
1899......	20·8	10·5	16·4	13·6	20·0	6·8	19·9	12·3	8·4	17·8	19·9	9·2
1900......	8·1	2·3	6·9	18·1	28·0	23·2	12·4	23·0	55·9	178·8	88·9	114·5
1901......	49·8	21·2	14·6	47·7	67·9	42·3	32·2	26·5	43·4	114·4	43·9	22·7

The following table shows the results of the examination of children in the different bazaars of Mian Mir made in October, 1901 :—

Table showing the Prevalence of Malaria in Mian Mir.

Locality.	Time of year.	Percentage of children infected with malaria parasites. ("Endemic index.")	Percentage with enlarged spleens.
British Infantry Bazaar	October, 1901	52 ·0	80
Royal Artillery Bazaar	,, ,,	35 ·0	75
Native cavalry lines ...	,, ,,	25 ·0	36
Syce lines (A)	November ,,	56 ·5	48
Syce lines (B)	,, ,,	20·0	20

The "endemic index" of some of these bazaars is a high one, and it is evident that in the months in which the examinations were made malarial fevers are very prevalent in Mian Mir and the liability to infection great.

In order to ascertain correctly the seasonal variations in the prevalence of malaria at Mian Mir, I have examined a number of the children in the bazaars as frequently as possible throughout the year, and these results, together with those obtained last year, may be tabulated as follows :—

To show the Seasonal Prevalence of Malaria in Mian Mir.

Locality.	Date.	Endemic index.	Spleen rate.	Number examined.
		Per cent.	Per cent.	
British Infantry Bazaar..	October 5, 1901	52 ·0	80	25
	November 25, ,,	20 ·0	38	25
	June 17, 1902	8 ·3	26	24
	July 28, ,,	8 ·5	37	35
	August 25, ,,	15 ·0	60	20
	September 17, ,,	32 ·2	65	31
	October 22, ,,	42 ·3	69	29
	November 19, ,,	27 ·0	57	24

From the above table we may say that the season of new infections in Mian Mir begins at the end of July or the beginning of August, and that the number of new infections increases steadily until it reaches a maximum in October. As soon as the endemic index begins to decrease, it may be assumed that new infections have ceased, and the sudden fall in the percentage of infected children in November affords

a proof of this. From November until July of the next year any cases of malaria that occur are relapses of former infections.

The Factors Determining the Prevalence of Malaria in Mian Mir.

In considering the factors on which the prevalence of malarial fevers in Mian Mir depends, the influence of the presence of *anopheles* mosquitoes must be taken first. After determining the endemic indices of the bazaars in October, 1901, our next object was to find infection in *anopheles* mosquitoes.

Only two species of *anopheles* were at all abundant, viz., *A. Rossii* (Giles) and *A. culicifacies* (Giles). Other species, which will be referred to later, were present but not in large numbers. *A. Rossii* was more abundant than *A. culicifacies*, but both species were found in all the bazaars, in the barracks of the troops, and in the hospital and jail.

In view of the fact that our other work in India had led us to the conclusion that *A. Rossii* was a very inefficient carrier of malaria under natural conditions, while *A. culicifacies* was a very good one, we selected a bazaar for the examination of *anopheles* where the two species could be caught in fair numbers in the same houses in order to compare their rates of infection.

The results of our dissections were as follows :—

Species of *anopheles*.	Number dissected.	Number with sporozoites in the glands.	Percentage infected with sporozoites.
A. Rossii	496	0	0·0
A. culicifacies	259	12	4·6

It is evident from these results that *A. culicifacies* is the chief if not the only carrier of malaria in Mian Mir, and the knowledge that *A. Rossii* is of little if any importance in conveying infection under natural conditions is of great importance in connection with anti-malarial operations.

Six species of *anopheles* have been found by us in Mian Mir, viz. :

A. Rossii. *A. pulcherrimus.*
A. culicifacies. *A. fuliginosus.*
A. Stephensi. *A. nigerrimus.*

The seasonal prevalence of these species in 1901—1902 was as follows :—All the species were found during October and the first week of November, 1901. *A. Rossii* was exceeding abundant and almost any number could be caught with ease in all the bazaars and barracks.

A. culicifacies was also present in fair numbers, though not so plentiful as *A. Rossii.* All the other species were comparatively rare, and it would have taken many weeks to catch a sufficient number of any of these species to render their dissection of advantage. During the second week of November the number of adult *anopheles* began to decrease rapidly, and November 28 was the last date on which any adult *A. culicifacies* were caught in the houses. Two adult *A. Rossii* were caught in one of the bazaars on December 5 after an hour's search, but these were the last adults seen during the winter of 1901, though search was frequently made during December. The larvæ also diminished very rapidly, but a few were still present in some old pools on December 20, and in pools which remained without drying up in Lahore throughout the winter, a certain number of larvæ could always be found, though no adult insects appeared to be present in the houses. In newly formed pools, however, no larvæ appeared, and it is probable that larvæ found during the winter are old ones which remain alive, but which are unable to develop into pupæ and adults until the spring.

A few new larvæ can be found in March, but adult *anopheles* are so few that it is difficult or impossible to detect them in the houses. Indeed, it is not until the middle of May that adult *anopheles* become sufficiently numerous in the houses to be detected by searching, and until this time larvæ also are scanty, though gradually increasing in numbers.

From the middle of May onwards the number of larvæ and the number of adult insects increases steadily to a maximum in September and the beginning of October.

In November the numbers begin again to diminish rapidly.

The seasonal prevalence of the two species *A. culicifacies* and *A. Rossii* does not exactly correspond. *A. culicifacies* appears much earlier than *A. Rossii.* Although moderate numbers of *A. culicifacies* could be caught in the bazaars during May and June, not a single adult *A. Rossii* was found until the beginning of July. As soon, however, as *A. Rossii* appears it increases very rapidly and in a short time becomes far more abundant than any other species. This may be accounted for by the fact that whereas *A. culicifacies* breeds chiefly in the irrigation water-courses which are running more or less throughout the year, *A. Rossii* is dependent for its breeding grounds chiefly on rain-formed pools, so that it does not appear in any abundance until the heavy rains of July commence (see Chart II).

By means of the following chart the seasonal prevalence of *anopheles* of malarial fevers, and the rainfall may now be compared.

CHART I.

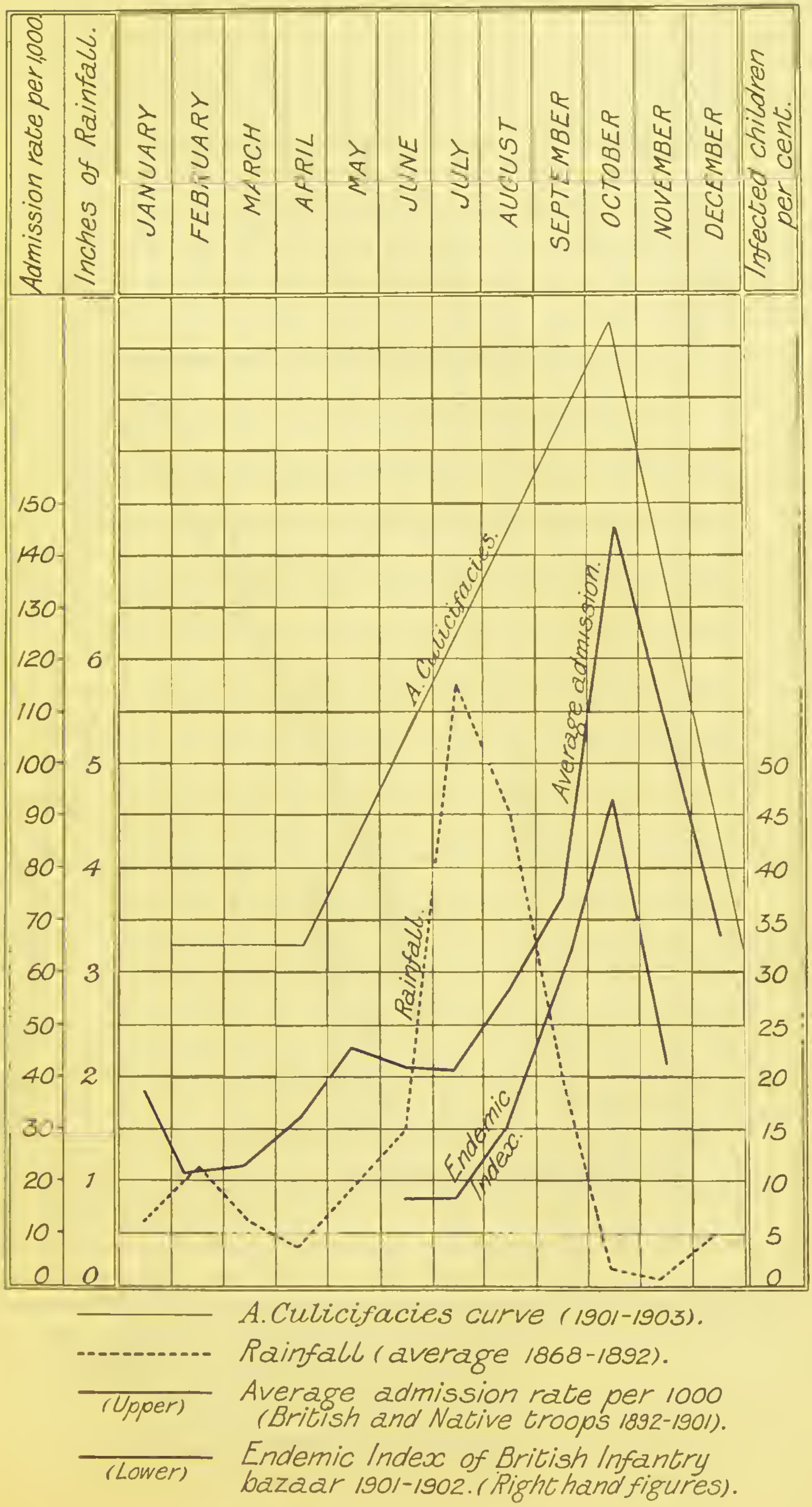
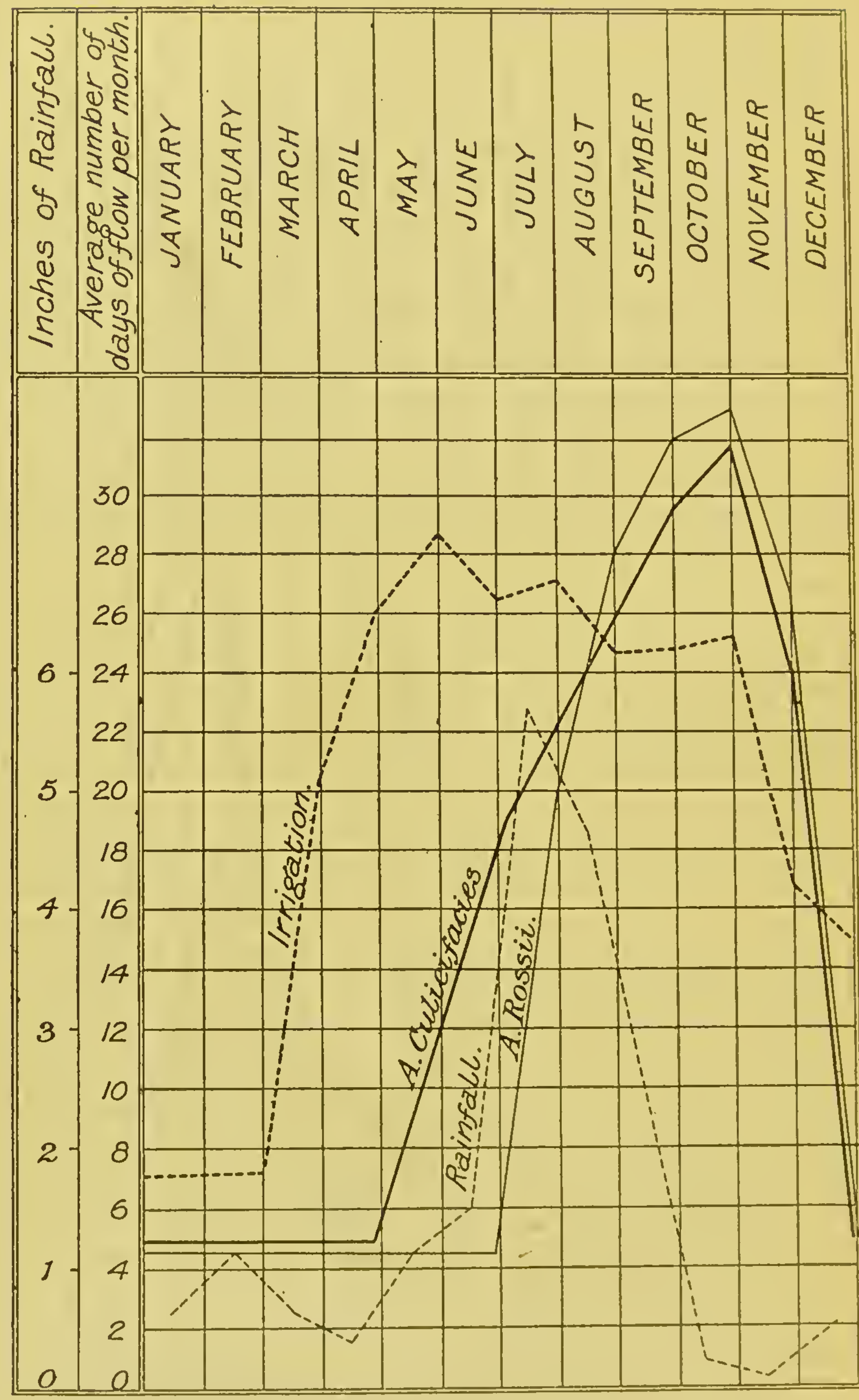

Admission rate per 1,000.
Inches of Rainfall.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Infected children per cent.
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6
5
4
3
2
1
0
50
45
40
35
30
25
20
15
10
5
0
A. Culicifacies.
Average admission.
Rainfall.
Endemic Index.
A. Culicifacies curve (1901-1903).
Rainfall (average 1868-1892).
(Upper) Average admission rate per 1000 (British and Native troops 1892-1901).
(Lower) Endemic Index of British Infantry bazaar 1901-1902. (Right hand figures).

CHART II.



Curve of irrigation supply to Mian Mir (average of 7 years).

Curve of A. Culicifacies.

Rainfall (average 1868-1892).

Curve of A. Rossii.

It will be seen from this chart that the seasonal prevalence of malarial fevers in Mian Mir corresponds very accurately with the prevalence of *anopheles*. In 1902 the first *anopheles* (*A. culicifacies*) were found in the houses on May 20. The first slight rise in the endemic index, *i.e.*, the commencement of the seasons of new infections, was noted a month later, which (allowing ten days for the parasites to develop to the sporozoite stage in the mosquito, and twenty days for the incubation period in man) is the earliest time at which new infections could occur. During August, September and October the abundance of *anopheles* and the endemic index of the bazaar increased together, and in November, with the almost sudden disappearance of adult *anopheles*, the endemic index quickly falls.

The connection between the flow of the irrigation water supply and the prevalence of *Anopheles culicifacies*, and between the rainfall and the prevalence of *Anopheles Rossii*, is shown in Chart II.

In addition to the influence of the presence of suitable breeding places formed by irrigation or by rain, the factor of temperature is, of course, a very important one in connection with the seasonal prevalence of *anopheles*, and the disappearance of all species of this genus in December is to be ascribed rather to the onset of the cold weather than to an absence of suitable breeding grounds.

As further illustrating the close connection which exists between the prevalence of malarial fevers in Mian Mir and the presence and relative abundance of *anopheles*, the conditions found in different bazaars and followers' lines may be given in more detail.

The inhabitants of these bazaars live in exactly the same class of house, derive their drinking water from the same source, and are exposed to the same climate and temperature. They are, in fact, under precisely similar conditions, except that the bazaars or lines are at different distances from breeding places of *anopheles*. As would be expected, the number of adult *anopheles* that can be caught in the different bazaars and lines varies with the distance from the breeding place. It will be seen from the following table that the prevalence of malaria is least in the lines that are furthest from a breeding place, and where consequently fewer *anopheles* can be found, and greatest in the lines that are nearest a breeding place, and where a larger number of *anopheles* are present :—

Table showing the Influence of Breeding Places of *Anopheles* on the Prevalence of Malaria in Mian Mir.

Name of locality.	Distance of nearest breeding place and its character.	Species of *anopheles* found, and abundance.	Endemic index per cent.	Spleen rate per cent.
British Infantry bazaar........	Irrigation watercourse, 30 yards Pools, 40 yards	*A. culicifacies*, *A. Rossii* abundant *A. fuliginosus*, *A. pulcherrimus*, *A. nigerrimus* rare	52	80
Royal Artillery bazaar.........	Irrigation watercourse, 172 yards Pools in bazaar	*A. culicifacies* not very abundant *A. Rossii* abundant *A. Stephensi*, *A. pulcherrimus* scanty	35	75
Syce lines A..................	Irrigation watercourse, 125 yards	*A. culicifacies*, *A. Rossii* abundant	56	48
Syce lines B..................	The same watercourse as Syce lines A, 584 yards	*A. culicifacies*, *A. Rossii* scanty	20	20

An experiment which I carried out during the year, and which will be again referred to in the account of the operations, also illustrates in a remarkable way how entirely the prevalence of malaria is influenced by the presence or absence of *anopheles*. This experiment was the removal of the inhabitants of the Syee lines A, referred to in the above table, into tents on a new site ¾ of a mile from the nearest irrigation watercourse and 600 yards from any pool. No *anopheles* were ever found in these tents, and the result of the experiment was the reduction of the percentage of infected children from 56 per cent. at the height of the fever season in 1901, to 4 per cent. at the same time in 1902.

Species of Parasite in Mian Mir.

Only two forms of the malaria parasite have been met with in Mian Mir, viz., the benign tertian and the malignant tertian forms. Out of 66 infections occurring in native children, 40 were with the benign tertian parasite and 26 with the malignant tertian.

Among the European troops the proportion of simple to malignant tertian infections is greater than this. Out of 18 infections among the men of the Royal Artillery in November, 1901, fourteen were with the simple tertian parasite and four with the malignant tertian.

No quartan parasites have been found in Mian Mir.

The Royal Artillery Lines.

On account of the wide area over which Mian Mir extends, it was decided to limit the anti-malarial operations chiefly to the lines of the Royal Artillery, which are more or less isolated from the rest of the cantonment. The foregoing general account refers to Mian Mir as a whole, and it is now necessary to add a few details regarding the portion of the cantonment in which the operations have been chiefly carried on.

1.—*The Sources of Infection of Anopheles in the Royal Artillery Lines.*

It has already been shown that a high percentage of the young children in the various bazaars and followers' lines are infected with malaria parasites, and as these children receive no treatment whatever, it may be assumed with some certainty that they form the chief source from which *anopheles* mosquitoes become infected.*

* *Vide* also 'Scientific Memoirs by Officers of the Medical and Sanitary Departments of the Government of India,' New Series, No. 2, 'Malaria in India,' by Capt. S. P. James, I.M.S., p. 61.

In the Royal Artillery lines there are five principal sources of this nature, viz. :—

(1) The Syce lines of the right battery. The infection of children in these lines is between 50 to 60 per cent., and the distance of the lines from the barracks is 175 yards.

(2) The hospital followers' lines. The infection of children in these lines is about 50 per cent., and they are situated within 30 or 40 yards of the hospital and prison.

(3) The Syce lines of the left battery. The infection of children is 20 per cent., and they are situated 400 yards from the barracks.

(4) The Royal Artillery bazaar. The infection of children is 35 per cent., and it is situated 440 yards from the barracks.

(5) The servants' quarters in the officers' bungalows. A large percentage of the servants' children who live in the bungalow compounds are infected with parasites, and they form a dangerous source of malarial infection to the Europeans living in the bungalows.

2.—*The Carrier of Infection in the Royal Artillery Lines.*

All the species of *anopheles* previously mentioned, except *A. nigerrimus*, are found in the Royal Artillery lines. As in other parts of the cantonment, *A. Rossii* is by far the most abundant, and enormous numbers of this species can be caught from July to November in the houses of the bazaar and lines, in the barracks, hospital and prison. *A. culicifacies* is also abundant throughout the lines, and adults of this species can be easily caught in the bazaars and barracks. This is undoubtedly the species by which infection is chiefly, if not entirely, carried in Mian Mir. Other species of *anopheles* are very rare in the Royal Artillery lines.

The Breeding Places of Anopheles in the Royal Artillery Lines.

In most places the breeding grounds of *anopheles* during the rainy season and those during the dry season can be sharply marked off from each other, but owing to the flatness of the ground in Mian Mir and to its impervious nature, a slight shower of rain produces almost the same conditions as regards the presence of breeding places as in other districts are only produced during the true rainy season. At almost any time of the year, therefore, numerous rain-formed breeding places may exist in Mian Mir, and it will be better for this reason to enumerate all the places where *anopheles* larvæ have been found at any time during the years 1901 and 1902, indicating at the same time the relative importance of each breeding place.

(1) The larger irrigation channels ("*Rajbahas*").

(2) The irrigation watercourses.

(3) Water spread over the gardens and fields for irrigation purposes.

(4) Pools formed by overflow of the irrigation watercourses.

(5) Pools left in the bed of an irrigation watercourse when the supply of water has been cut off.

(6) A few large ponds or "tanks" and a large number of small stone reservoirs for collecting water in the gardens.

(7) Rain-filled pools, surface drains, rain-formed pools on flat areas of ground, etc.

(8) Domestic utensils. Tins and buckets of water kept in the lines in case of fire and for other purposes.

(9) The swimming baths.

(10) The small surface drains which carry off water from the stand-pipes, wells, cook-houses, baths, etc.

(11) The wells.

(1) *The Larger Irrigation Channels.*—The velocity of the water in the main "*Rajbaha*" bringing water into the Royal Artillery lines is considerable, and except at the bridges which cross the channel at many places, and which check the flow of water, larvæ are rarely to be found.

(2) In the smaller distributing channels, however (irrigation water-courses or "cuts"), which form a network throughout the cantonment, the flow of water is slow, and is frequently further impeded by a thick growth of grass and vegetation along the sides of the water-course.

Many of these ditches also have no outflow, and end only in the basin of a Persian wheel, so that the water in them is quite stagnant except during the time that the Persian wheel is working (about 3 hours daily).

All these irrigation watercourses form ideal breeding places, and are the main source of *anopheles*—especially of *A. culicifacies*—in the cantonment. Many larvæ can, as a rule, be found in them throughout their length, but they are especially numerous in places where grass and weed are growing at the edge, and also at the bridges where the flow of water is checked.

(3) The water distributed over the land dries up quickly as a rule, but even in this dangerous breeding places of *anopheles* are sometimes found. The young trees in Mian Mir are planted along the bed of small distributing ditches, and round each tree it is usual to dig the ditch deeper so that a pool of water may be formed. These pools are frequently so deep that all the water given in one day does not dry up before the next supply comes on the following day, and I have frequently found *anopheles* larvæ and pupæ in these pools.

Similar pools are formed in many parts of the gardens of the

officers' bungalows, owing to the unevenness of the ground. The supply of irrigation water to the cantonment is a very intermittent one, and during the comparatively short periods in which irrigation water is available, it is everyone's object to flood their gardens as much as possible. Owing to the impervious nature of the soil and to the general levelness of the ground, if more water is given to a garden than can all be soaked up in a day, it collects and forms pools in any depressions of the ground. These pools being replenished daily, may last for ten days or more.

(4) When the irrigation water supply is cut off from the cantonment, many pools are left in the watercourses. The number of larvæ found in these pools varies considerably. In many of them no larvæ can be found, in others, however, larvæ are so numerous that the surface of the pool is almost covered with them. In the winter these pools are of great importance, for during December, January and February, when the irrigation water supply is cut off for long periods at a time, *anopheles* larvæ can remain in a resting condition in the pools under the bridges until the warm weather comes again. This is, in fact, the chief if not the only means by which *anopheles* mosquitoes can tide over the cold of winter in Mian Mir.

During the cold winter months no adult *anopheles* can be found in the houses, but in such pools as these larvæ are found in a more or less "hybernating" condition, that is, they do not grow at all, or grow extremely slowly, until the warm weather comes again.

(5) Numerous pools are formed by overflow of the irrigation watercourses, and large numbers of larvæ (*A. Rossii*) are found in these. Occasionally, from the breaking down of the sides of a watercourse, a very extensive overflow is made, forming a pond which may last for some months. In such an overflow the larvæ of *A. Fuliginosus* and *A. nigerrimus* were found.

(6) In the brick-lined "tanks" for bathing purposes, which are found near some of the bazaars, larvæ are rarely present, but there are also a few ponds, the sides of which are not brick-lined, and in these *anopheles* larvæ are not uncommon. In every garden there are a number of small brick tanks for collecting water for irrigating purposes. They frequently contained *anopheles* larvæ.

(7) Rain-formed pools are exceedingly numerous, and it is difficult to realise the difference which even a small shower of rain makes in the aspect of the cantonment. Large ponds of water cover the plain on every hand, and for 2 days after a few hours' rain parades on the Royal Artillery parade ground become impossible. To reach the Syce lines of the batteries one has to wade through water for several hundred yards. The whole cantonment is in a similar condition. Most of these large sheets of water dry up under the hot sun in 2 or 3 days, but pools of water remain in depressions of the ground and in all the surface drains

until the next shower of rain. The condition indeed, is one of the presence of innumerable pools constantly exposed to a hot sun, and constantly being replenished with fresh water—a condition eminently suitable for the breeding of *anopheles*. It is not surprising, therefore, that in all these pools and in all the surface drains numerous larvæ are found during July and August.

(8) Two large covered-in swimming baths for the troops are present in the Royal Artillery lines. Although these are constantly used by the men, numerous *anopheles* larvæ were found in both the baths during the summer. The baths take about 2 days to empty and nearly a fortnight to refill, and the water in them is not completely changed more than three or four times during the whole summer.

(9) The waste water from the wells, standpipes, cook-houses and baths, is carried off in small brick channels 2 or 3 inches deep. In all of these channels *anopheles* larvæ were found at different times of the year.

(10) Numerous tins and earthenware vessels of water are kept in the lines in case of fire and for other purposes. They frequently contained large numbers of *anopheles* larvæ.

(11) As a rule *anopheles* larvæ were not found in the wells, but in several which are only occasionally used larvæ were found.

The main irrigation *watercourses and other breeding places* are shown on the plan.

The above is a brief description of the conditions under which malarial fevers prevail in Mian Mir, and I may now refer to the operations which have been undertaken to combat it.

It should be noted that the primary object of the operations was to test the efficacy of mosquito destruction, and the chief efforts have, therefore, been directed to this end.

In an experiment such as this it is necessary to have some definite tests by which success or failure can be measured.

The following were the tests we proposed to employ :—

(1) Tests of a reduction in the number of *anopheles* mosquitoes.

(*a*) Larvæ. It can be made evident that though in previous years at the same time of the year larvæ were readily found, yet in the year of the experiment they were not so abundant.

(*b*) Adult *anopheles*. In any given bazaar or barracks it is possible for one who has regularly collected *anopheles* there, to say with certainty that they are more or less abundant. Also by making observations in a bazaar within the area of operations, and in one outside the area, it is possible to ascertain whether the operations are successful.

(2) Tests of a reduction in the amount of malaria.

(*a*) A reduction in the number of admissions for malarial fevers among the troops.

(*b*) A reduction in the percentage of infection with malaria parasites among the troops.

(*c*) A reduction in the amount of malaria in the regimental bazaars as measured by the percentage of children found infected with malaria parasites.

The first of these tests is probably the least to be depended upon, because hospital statistics may be affected by many causes; still unless it were possible to show a marked reduction in the number of admissions into hospital for "ague" the operations could not be considered successful. The most conclusive test of all would be the reduction of the percentage of infected children in the regimental bazaars. If as a result of the operations it could be shown that a marked reduction in the numbers of *anopheles*, and in the percentage of infected children in the regimental bazaars had occurred, the success of the operations would be proved.

Part II.—The Operations.

The operations were commenced on April 2, 1902. They will be described under the following headings:—

(1) Operations directed towards the destruction of mosquitoes.

(2) Operations directed towards the destruction of malaria parasites in infected individuals, or towards the removal of such individuals from the vicinity of the area of operations.

(3) Prophylaxis by quinine.

I.—*Operations against Mosquitoes.*

In order that all parts of the area chosen (viz., the Royal Artillery lines), might be systematically examined and dealt with week by week, I divided it, for the purposes of the work, under the following plan.

(1) The irrigation watercourses, viz., the main irrigation channel and its six chief branches, called respectively the first to the sixth branch, with their offshoots which supply the whole area of the Royal Artillery lines.

(2) The "Royal Artillery bazaar section," comprising the bazaar and the area surrounding it.

(3) The "barracks section," comprising the area round the main barracks, the hospital and prison.

(4) The "stables section" comprising the area round the stables, Syce lines, etc.

(5) The "gardens section" comprising the area of the officers' bungalows and gardens.

(6) The "pools section" comprising all the areas containing more or less permament pools.

One or more of these seetions were carefully examined daily in regular order, so that no part of the lines could be left unexamined and unoperated upon for more than a week at a time. It was not possible of course to examine the whole of the watercourses in one day, but by taking one watercourse and the section near it (*e.g.*, the first branch and the bazaar section) the same day, and another branch and its adjacent section the next day, and so on, the whole of the area could be gone over during the week.

Methods Employed.

These were principally confined to operations against larvæ.

The methods used in the irrigation watercourses (running water) and in pools, and other eollections of stagnant water, must be described separately.

(1) Methods employed in the irrigation watercourses.

(*a*) It has already been pointed out that the irrigation watercourses form the chief source of *anopheles* (especially of *A. culicifacies*) in the Royal Artillery lines, and that the larvæ are most numerous in these channels wherever any grass or weed is growing at the edges. Experiments which we had made in November 1901, pointed to the fact that if the sides of an irrigation watercourse are cut clean and smooth, so that the flow of water is not impeded, and if all grass and weed under which larvæ can shelter, is removed from the edges, the number of larvæ found in such a watercourse will be greatly diminished. The chief method employed was, therefore, based on this fact, and it was hoped that by constantly keeping the sides of the watercourses smooth and free from grass for many months, they might be made permanently unsuitable for the breeding of *anopheles* larvæ.

(*b*) A more effective and permanent means of carrying out the above principle was to have one of the watercourses lined with brick and smoothly plastered with cement. This was done with a length of watercourse running through the centre of the lines and in front of the main barracks and hospital (Plan of lines, p. 54. PP′).

(*c*) For some weeks during June and July I tried the method of drying out and cleaning each branch once every 10 days. By this

plan all the larvæ present in the watercourses were killed before they had time to reach the pupa stage, but on account of the expense of drying out the channels, for most of the water had to be bailed out with buckets—and the fact that stopping the water at intervals interfered to some extent with irrigation—the plan was discontinued.

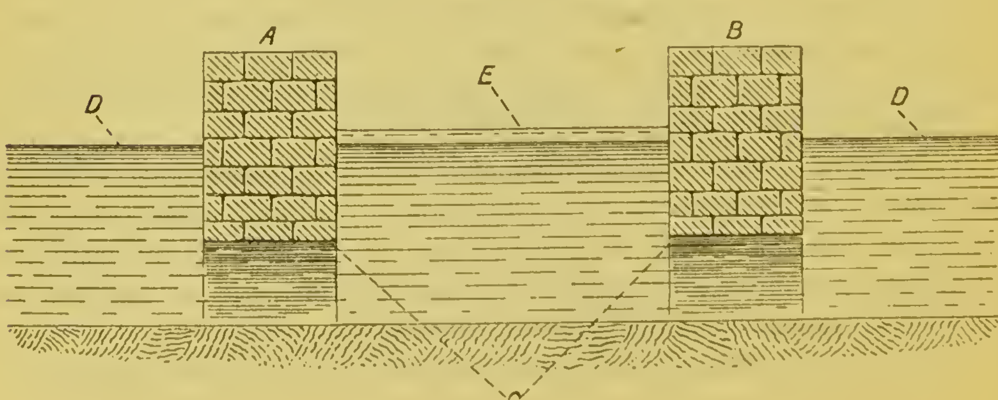
(*d*) The method of pouring oil on the watercourses. I have already mentioned that many of the watercourses contain almost stagnant water, and for these the plan of destroying the larvæ with kerosene oil naturally suggests itself.

Some experiments which I made on a plot of grass-land, kindly lent me for the purpose by the officer commanding the Royal Artillery, showed that even large quantities of kerosene oil poured round the roots of the grass had no injurious effect whatever, nor did it give any bad taste or smell to the grass, but, in spite of this, I consider that it would be inadvisable to use a method from which there would be a danger of any kerosene oil reaching the crops. Nor do I think it would be advisable to use a preparation such as "larvicide," which colours the water red. If in any year the crops were poor, it would certainly be put down by natives, and even by many Europeans, to the use of either of these substances.

With proper precautions, however, it is quite possible to pour kerosene oil on the watercourses in certain places without any of it reaching the land, and on this point my experiments showed the following results:—

(1) Kerosene oil poured on a watercourse between any two bridges does not pass beyond either. This is due to the fact that the bridges over the watercourses in Mian Mir are what are called "syphon bridges," that is, the depth of water in the watercourses is always greater than the height of the arch of a bridge, so that, as the oil floats only on the surface of the water, it cannot pass through the arch of the bridge. This is illustrated in the diagram below (fig. 1).

Fig. 1.



(2) For the same reason, if a deep board is placed over the mouth of a Persian wheel, half the board being under the surface of the water and half above it, oil can be safely poured on the watercourse without any of it being taken up in the buckets of the wheel.

(3) The water supply to the canals is frequently shut off for a week or more at a time. When this is done numerous pools are left in the watercourses, and, while these are drying in the sun, oil may be poured on them with great advantage.

The application of kerosene oil to the watercourses is therefore limited, and can only be carried out under careful supervision.

II.—*Methods employed for Pools and other Collections of Stagnant Water.*

(*a*) Pools formed in connection with irrigation. These comprise, firstly, more or less permanent large pools, formed from time to time by the overflow of a watercourse, or the breaking down of its banks. Such pools were, as far as possible, prevented from being formed by paying constant attention to the watercourses, building up their banks wherever there was danger of overflow, and digging them out, in order to keep the water level below the height of the bank. When any such pools had formed, they were temporarily covered with a layer of oil, and afterwards filled in with earth. Secondly, a number of small pools are formed in the gardens, by reason of the fact that all the water given to an area in one day does not always sink in or dry up before the next day's supply of water reaches it. Any small pool formed in this way is replenished each day, so that a pool lasting 10 or 12 days is made.

In the weekly examination of the garden section, pools of this nature containing *anopheles*' larvæ were frequently found. As the owners of the gardens might object to kerosene oil being used on land where plants and flowers were growing, the water of these pools were either drained away, or emptied out and thrown over the land.

Thirdly, numerous pools are left in the beds of the watercourses after the supply of water is cut off. As a rule, these pools contained many larvæ. By connecting one pool with another throughout the length of a watercourse, it was often possible to dry the whole of these pools quickly; where this could not be done, oil was poured on the separate pools. After the water supply is cut off, a pool also remains in the bottom of each *jhalar*. These pools were dried out by emptying out the water with tins and buckets.

(*b*) Rained-formed pools. These are very numerous during the months of June and July. First, there are the large shallow ponds of water formed almost throughout the lines on the level plain after every shower of rain. In the Royal Artillery lines, the chief ponds of

this nature are formed on the parade ground, on the football ground, and near the Royal Artillery bazaar. As a rule, these superficial pools dry for the most part in 2 or 3 days, but if before the end of that time more rain falls they remain sufficiently long for larvæ to develop in them. By digging small channels in various directions, it was comparatively easy to drain these away into the irrigation water-courses, and this was done every time rain fell.

More dangerous breeding grounds are formed by the *surface drains* which exist throughout the lines. From the fact that these drains have little or no fall, rain accumulates in them for many days, and, after a week or less, they swarm with *anopheles'* larvæ. Owing to the large amount of water they contain, they are difficult to deal with. Some were dried out with buckets, and on others oil was poured. During 1902 the rainfall was a very small one, but in years of heavy rain a great deal of labour would be required to keep these drains free from larvæ.

(*c*) Permanent tanks and pools. One large tank near the Royal Artillery bazaar was filled in by the cantonment authorities. Over 250 smaller tanks and pools have been filled in by contract labour.

(*d*) Numerous other breeding places have been dealt with as they have been discovered. The small drains carrying off water from the baths, stand-pipes, etc., in which larvæ were frequently found, have been swept out regularly, tins and buckets kept full of water in the lines in case of fire have been emptied weekly, as have also the horse troughs and cisterns. The only breeding places which have not been dealt with in any way are the swimming baths. Numerous *anopheles'* larvæ were found in the two large swimming baths in August and September. As they take 3 days to empty and a fortnight to refill, it was difficult to suggest any effective method of preventing them from acting as breeding places.

The following details of the work are taken from my diary during the year :—

The operations were commenced under favourable circumstances, for at the end of March no adult *anopheles* could be found by careful search in the houses, and, as the irrigation water supply had been cut off for some time, there were comparatively few breeding places to be dealt with.

The first object was to get all the irrigation watercourses thoroughly cleaned out, and their edges made smooth and free from grass and weed. Twenty coolies, under a head man of the Canal Department, were engaged, and work on the watercourses was started on April 2. The fresh supply of water entered the

canals on April 9, and a very few *anopheles'* larvæ were found in them on the 13th and 14th. Some of the watercourses were almost hidden from view by thick pampas grass and branches of trees, which grew on their banks, and, as it was very necessary that this thick growth of vegetation should be cleared away as quickly as possible, so that the watercourses might be converted into clean channels, exposed to the sun and air, it was found desirable to employ a larger staff of temporary men to carry out this first work. From April 21 to the end of the month, therefore, between forty and fifty coolies were employed daily on the irrigation watercourses. By the end of April all the watercourses in the area of operations had been thoroughly cleaned out, all the grass growing on their banks had been cut down, and their edges had been made as smooth as possible. On April 20 the water supply of the canals was again shut off. As a result of this, many pools were left in the watercourses and in the *jhalars*. A few *anopheles'* larvæ and numerous *culex* larvæ were found in all these pools. Most of them were dried out by the men with tins and buckets, but, as an experiment, a few of the pools were covered with a layer of kerosene oil. This killed all the larvæ present in about 20 minutes, but, three days afterwards (on the 24th), young *anopheles'* and *culex* larvæ were again found in these pools. On the evening of April 24 heavy rain fell for some hours. This caused many pools throughout the area, and gave an indication of what pools would be most dangerous during the rainy season. A map of the more permanent pools was now made, and additional men employed to commence filling them in with earth. In the meantime the water of the superficial pools was drained away by digging small channels leading into the irrigation watercourses, and the more permanent pools were dried by bailing out the water with buckets, and throwing it on the open plain, where it would dry up quickly in the sun.

After all the watercourses had been dealt with for the first time in the manner described, two men were permanently applied to each branch. Their duties were :—

(1) To keep the edges free from grass and weed.

(2) To keep the sides smooth and regular by scraping away the earth at some places, and filling in any small bays and irregularities at others.

(3) To constantly remove all leaves, sticks, and other floating *débris*. For this purpose the men were provided with shallow round baskets, and, by walking in the water, scooping the basket along the edge underneath the surface, all the floating *débris* was collected and thrown out on the bank. This was a very important part of their work, for dead leaves were constantly

> falling into the water from the trees above, and under their shelter larvæ were constantly found. If left alone, the leaves collected in a thick mass at each bridge, impeding the flow of water, and forming an excellent breeding ground for larvæ.

Two men could in this way go over their own branch three times daily. They were constantly supervised and directed in their work by myself, my hospital assistant, and by an overseer of the canal department.

The irrigation water supply started again on May 6, and was not shut off for more than two or three days at a time throughout the summer.

In spite of the constant cleaning operations, a few *anopheles'* larvæ, and a fair number of *culex* larvæ, were found in the watercourses on May 12.

By covering the shallow baskets with muslin, the men were able to catch and destroy a good number of these larvæ at the same time as they collected the leaves. On May 15 the bricking of the watercourse running through the centre of the lines was commenced, and for this purpose the water was shut off from this branch and the others which obtained their supply from it.

On May 14 slight rain fell, and the pools formed were treated in the same manner as on the same previous occasion. The filling in of permanent pools with earth and the cleaning of the watercourses was continued steadily, but in spite of this a eertain number of *anopheles'* larvæ were found in all the watercourses from May 15 onwards.

Along the smooth edges they were not as a rule to be found, but in many of the watercourses roots of trees projected into the channel, and in their shelter larvæ were generally present. All the larger roots were therefore cut off to the level of the bank with hatchets, and so got rid of.

From May 30 to June 3 I made careful observations throughout the area of operations, and throughout another part of the cantonment, to ascertain whether any success in the reduction of the number of larvæ and adult mosquitoes had been attained. The results showed that although in the area of operations a few larvæ could be found in all the watercourses *by careful search*, the number present was far less than in the uncleaned watercourses in other parts of the cantonment.

In the watercourses of the British Infantry bazaar, for example, an enormous number of larvæ were found, and even without dipping with a tin they could be seen among the grass and weed at the edges. It was evident that up to the end of May the breeding of larvæ in the watercourses of the area of operations had been prevented to a very considerable extent. Corresponding success was attained with regard to the number of adult insects to be found in the houses. On June 3, after eareful search for over an hour, I could not find a single adult

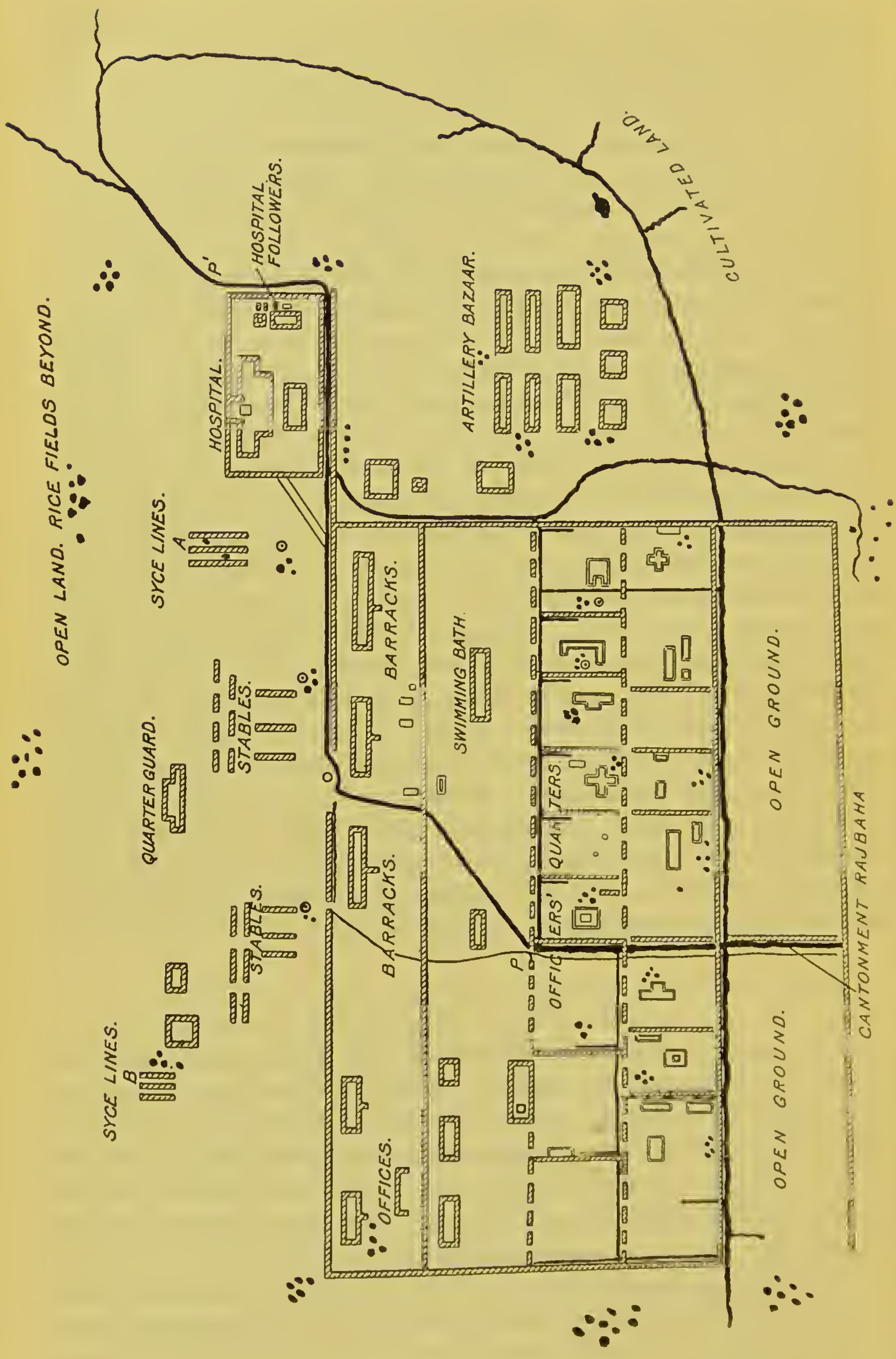
anopheles in the Royal Artillery bazaar. On the same day I caught ten adult *A. culicifacies* in the British Infantry bazaar in about half-an-hour without much difficulty. During June, however, the number of larvæ in the watercourses of the area of operations increased considerably, in spite of the same methods being continued. I have already mentioned that by reason of some of the watercourses having no outlet, the water in them is stagnant except for about 3 hours a day while the Persian wheels are working. However clean they are kept, they form, for this reason, prolific breeding grounds for *anopheles.* Finding that cleaning operations were not completely successful in preventing larvæ from appearing in large numbers in these watercourses, I tried the plan from June 15 of making a *bund** at the beginning of each branch, emptying out all the water in the branch, allowing it to dry in the sun, and again letting in fresh water (Method (*c*) pp. 47—48). By this means all the larvæ present in the branch at the time were killed. During the month of June I found that larvæ required 10 to 12 days to develop from the very young stage into adults, and to kill all larvæ it was, therefore, necessary to dry each branch about once every 10 days. I carried out this plan for six weeks, but on account of the expense of drying out the branches, which was done partly by working the Persian wheels, and partly by bailing out the water with tins and buckets, and the fact that such operations interfered to some extent with irrigation, I ceased this plan about the middle of July, and returned to the method of keeping the edges of the watercourses clean and removing all floating leaves and *débris.* From the beginning of June the operations carried on, and the results of examinations for larvæ and adult mosquitoes, may be more conveniently described under the headings of the various sections into which the area of operations was arbitrarily divided.

I. *The Watercourses.*

In the area of operations there are ten watercourses. As the methods employed and the results obtained were practically the same in all, it will be sufficient to give the details concerning one watercourse only, noting that similar operations were carried out on different dates in all the other watercourses, and practically similar results obtained. The following account refers to the first watercourse through the gardens.

On June 7 a fair number of nearly full-grown *anopheles'* larvæ were found in this branch. A *bund* was made at its commencement, and it was dried out and cleaned on the 8th. Fresh water was let in on the 9th, but on the 12th very young *anopheles'* larvæ were again present. The number and size of the larvæ found gradually

* Bund = a dam or embankment.



PLAN OF ROYAL ARTILLERY LINES.

increased, and on the 19th this branch contained a good many nearly full-grown larvæ. The water was therefore again shut off on the 20th, and the watercourse was dried and the mud it contained dug out.

As irrigation was not required from this branch at the time, fresh water was not let in until the 26th of June. Three days later a few very young larvæ were again found. Cleaning of the sides and removal of leaves was carried on daily, but on July 8 many young *anopheles*' larvæ and a few full-grown ones were found throughout its length. On July 9 the water was again shut off and the branch dried, but before the drying was completed the branch was refilled by rain on the 10th, so it was again dried and fresh water let in on the 13th. New broods of larvæ were not found again until the 17th. On the 22nd there was very little water in this branch, and numerous full-grown and young *anopheles*' larvæ were found in it. As the supply of water was so small that none could reach the Persian wheel, oil was poured on it, which killed all the larvæ. Sufficient water for irrigation did not reach this branch again until the beginning of August, and on August 9 young larvæ were found. Full-grown larvæ were not found until the 22nd, when this branch had again become so shallow as to form only a series of pools. These pools were dried out. With the return of the irrigation water supply, cleaning operations were carried on daily, but in spite of this, many full-grown larvæ and innumerable young ones were again found on August 31. With proper precautions to prevent any oil reaching the Persian wheel (*vide* Method (*d*) p. 48), I therefore covered the whole branch with a layer of kerosene oil. On the next day no larvæ at all were found. The good effect of the oil lasted about a week; on September 7, however, young *anopheles*' larvæ were again found, and on the 15th numerous full-grown larvæ. With the same precautions as before, oil was again poured on the first half of the branch on September 17, and on the 18th no larvæ were found except a few at the very end, where the oil had not reached. On September 24 a few very young larvæ were again found—the effect of the oil having passed off—and on the 28th, when the branch was so shallow as to form only a chain of pools, full-grown larvæ were present. These pools were dried out. At the beginning of October the irrigation water supply was cut off, and this branch was dry throughout its length on October 3. The supply recommenced on October 9, and young larvæ were found on the 14th. On the 22nd it contained a good many full-grown larvæ and some pupæ, but on this date the irrigation supply was again cut off, so that on the 23rd this branch contained only a few pools, which were easily dried out. On October 24 fresh pools were formed by rain, but on the 27th no larvæ were found in these pools and they were dry on the 28th. The irrigation supply was resumed on November 5, but it only ran for 3 days, and on the 11th, with the exception of some pools under the bridges, this branch was dry throughout. A few *anopheles*' larvæ were found in these pools. They were dried out, and together with all the other watercourses this one remained dry until the irrigation water supply was

again given on November 29. This branch had now been dry for fully 20 days, and as at this time no adult *anopheles* could be found in the houses, it afforded a good opportunity of testing whether any adults were really present (though none could be detected by careful search) or not. If adult *anopheles* were present in the houses, it is reasonable to suppose that they would again lay their eggs in the branch as they had done throughout the year. No young larvæ have, however, been found in this or any of the other branches from the time of arrival of fresh water on November 29 up to the present date. On December 5 the irrigation supply was again cut off and a chain of pools left in the branch. These were allowed to dry in the sun, and afforded exceedingly favourable breeding places, but no larvæ appeared in them or in the pools of any of the other branches.

A few details may now be given regarding the watercourse, which was rendered permanently smooth and free from grass and weed by lining it with bricks plastered with cement. The total length of the bricked portion is 4,985 feet. Before being bricked it formed an exceedingly dirty weed-grown ditch, containing almost stagnant water, running through the centre of the lines and within a few yards of the front of the barracks, the military prison and hospital (*vide* plan of Royal Artillery lines, PP′). In addition to its being a prolific breeding ground for *anopheles* it formed a depositing ground for most of the old tins, bottles, and rubbish of all descriptions from the lines and barracks. As a result of the bricking it has been converted into a clean-flowing channel about 5 feet wide and 4 feet deep, running with moderate velocity and in an efficient manner. A sliding door has been placed at its commencement, by means of which the flow may be regulated and the channel flushed out. The bricking was commenced on May 15, and completed at the end of July.

Although from a sanitary point of view the bricking of this watercourse has been of great benefit, the result, from the point of view of destruction of *anopheles*' breeding places, has not fully realised our expectations. We had hoped that after bricking this channel, the flow of water in it would be sufficiently swift to entirely prevent its acting as a breeding place. This, however, is not the case, and if left entirely alone, it still remains as a breeding ground of *anopheles*, though not nearly to the same extent as formerly. This is due partly to the fact that the flow of water is still only very moderate, and partly to the numerous leaves which fall into the water, and collect at the bridges, where they form a suitable shelter for larvæ.

During part of August I did no cleaning operations whatever on this watercourse, with the object of testing the efficacy of the work of bricking. Although no larvæ could, as a rule, be found along the clean, plastered sides of the channel, they were numerous at the bridges and under the leaves. After this I constantly employed two

men with baskets to take out all the leaves, and to keep the sides of the channel clean and free from mud. As a result of this the number of larvæ to be found was very much diminished, and it may fairly be said that, while the water is actually running, one or two men constantly employed in this way could keep this bricked watercourse almost completely free of *anopheles*' larvæ. When the irrigation water supply stops, however, a number of pools remain in this watercourse, as in the unbricked ones, and these would also require constant attention.

The above descriptions may be taken as fair examples of the methods employed, and the results obtained in all the watercourses of the area of operations. It will be seen that though various plans were carefully tried, it was not possible to prevent *anopheles*' larvæ from constantly appearing in the watercourses in large numbers. By continuous efforts it is possible to check the breeding to a certain extent, and to kill a great many of the larvæ, but if the measures are stopped for even a week at a time, the condition becomes almost the same as before.

II. *The Royal Artillery Bazaar Section.*

On June 11 no breeding places except the irrigation watercourses were found in this section. On the 17th a few *anopheles*' larvæ were found in a garden pool in front of the bazaar. This pool was dried out, and on the 22nd no breeding places were found. Search for adults was frequently made during June. On the 3rd no adult *anopheles* were found after careful search in many of the houses, stables, and sheds. On the 16th I found four adult *A. culicifacies* in one of the stables after nearly an hour's search. By the 26th the number of adult *A. culicifacies* present in the houses had increased considerably, but they were still scanty, and difficult to catch. This was in marked contrast to other bazaars in the cantonment, where from the beginning of the month adult insects (*A. culicifacies*) were present in sufficient numbers to be caught without much difficulty in many of the houses. No adult *A. Rossii* were caught in any of the bazaars during June.

During July a large number of rain-formed breeding places were found from time to time in this section. These consisted chiefly of large and small pools formed by holes dug for road making, building, and other purposes. Along one roadside there were twenty pools, averaging 5 feet long by 2 feet deep, which after a short time swarmed with the larvæ of *A. Rossii.* Such pools were temporarily covered with a layer of oil, and afterwards filled in with earth. The surface drains in this section were found also to afford excellent breeding places for *anopheles*, and during this month it required great care to keep them free from larvæ. Another class of breeding place found

during this month were the drains and pools formed by the waste water of the wells. This waste water of the wells is difficult to deal with, for it cannot be drained away on account of the levelness of the ground. In this section it was dealt with by collecting it into a temporary deep pool, which was kept constantly covered with a layer of oil.

During July, in spite of constant attention being paid to all breeding places, the number of adult insects (*A. culicifacies* and *A. Rossii*) found in the houses increased considerably, and throughout the month specimens of both species could be caught fairly easily at any time.

During August the chief breeding places found in this section were the roadside surface drains, the deep pools by the roadsides, the drains carrying off water from the wells and from the bazaar, a few irrigation pools in a garden in part of the bazaar, and the *gumlahs** of water kept outside each house. During part of the month the road in front of the bazaar was being relaid. In road-making it is the practice of the contractors to use the surface drain which runs at the side of the road they are laying as a reservoir of water. One end of the drain is closed by a barrier of bricks and earth, and the drain is then filled to the brim with water for use in their work. A collection of water 50 yards or more in length is thus made, which quickly becomes swarming with *anopheles'* larvæ. Within the limits of the cantonment the practice of filling these drains with water was stopped with some difficulty, as the workmen refused to continue laying the roads unless it was allowed. Outside the cantonment limit it was still carried on, and the constant emptying out of the water in these drains every few days required much labour. In the absence of urgent work of this kind, my men were employed filling in the roadside pools with earth. In the meantime all pools were kept covered with a layer of oil. In this month it was found necessary to repeat the oiling of pools at least every three days, as the larvæ developed so rapidly, and under the great heat the oil quickly evaporated.

During the month of August a very large number of adult *A. Rossii* were present in the houses of the bazaar. The number of adult *A. culicifacies* had also increased somewhat, though they were not by any means as plentiful as *A. Rossii*, nor were they so common as in other bazaars of the cantonment where no operations had been carried on.

During September and October the same class of breeding places had to be dealt with. Most of the pools had by this time been filled in with earth, and as the rains had almost ceased the work was less. Constant inspection, however, was necessary to keep larvæ from appearing in every collection of water in and around the bazaar. *Gumlahs* of water had to be constantly emptied, shallow drains to be swept out, and a layer of oil kept constantly on overflow pools of the

* Gumlahs = earthenware vessels.

wells and other collections of water that could not be dealt with in any other way. During September the filling in of a large pond near the bazaar was completed by the cantonment authorities.

At the beginning of September there was a temporary diminution in the number of adult insects to be found in the houses, but at the end of the month, and during October, their numbers were certainly as great, if not greater, than during August.

A few specimens of other species, viz.: *A. Stephensi*, *A. pulcherrimus*, and *A. fuliginosus*, were also found during September.

During November the development of larvæ was less rapid, and the number to be found in the different breeding places gradually diminished. A progressive decrease in the number of adult *anopheles* to be found in the houses also occurred, and at the end of this month it was difficult to catch any specimens of either species.

At the beginning of December no adult *anopheles* of any kind could be found in the houses, and from this time onwards no fresh batches of larvæ have appeared in any of the breeding places. A similar disappearance of adults and larvæ was, however, noted in other parts of the cantonment where no operations had been carried on.

III. *The Barracks Section.*

On June 4 *anopheles'* larvæ were found in the shallow drains carrying off water from the swimming baths, and in the overflow water of the stand-pipes. A sweeper was appointed to keep all the shallow drains in the vicinity of the barracks swept out daily. On the 14th *anopheles'* larvæ were found in shallow pools near the Persian wheel of the fourth Branch, and in its stone water reservoir. On the 24th *anopheles'* larvæ were found in a number of kerosene oil tins which are kept full of water near No. 8 Barrack, and on the 30th larvæ were found in the stone water reservoirs of the cook rooms.

Adult *anopheles* (*A. culicifacies*) were first found in the barracks on June 16. Throughout the month, however, the number of adult insects in the barracks was very small. No *A. Rossii* were caught in the barracks during June.

During July rain-formed breeding places were abundant in this section; all the storm-water surface drains especially formed good breeding grounds for *A. Rossii.* After each shower of rain, also, large areas of water collected in many parts of the lines, and a number of deep trenches which had been made to mark off the boundary of the cantonment grass farm area also became filled with water, which in two or three days swarmed with larvæ. The shallow collections of surface water were drained away into the irrigation canals. Collections of water in pools, drains, or trenches were either emptied out, or covered with a layer of oil.

The number of adult insects found in the barracks increased quickly during this month. On July 8 large numbers of *A. Rossii* were collected from the barracks and harness rooms, and on the 11th these rooms also contained a fair number of *A. culicifacies*. Throughout the month, however, the number of adult *anopheles* present in the barracks and other parts of this section was not nearly so great as in parts of the cantonment where no operations had been carried on.

The following is a list of the places where *anopheles'* larvæ were found in this section during August :—

(1) Numerous waste-water pools from stand-pipes, cook-houses, and wells.
(2) Small brick drains leading away from the above.
(3) Numerous rain-formed pools in the surface (storm-water) drains, and on the open plain.
(4) Tins of water kept near the barracks and hay-ricks in case of fire.
(5) The swimming baths.

These breeding places (except the swimming baths, for which no method could be devised) were dealt with regularly. During the month the number of adult *anopheles* present in the barracks increased considerably.

The breeding places during September and October were similar to those in August, and had to be regularly dealt with, the section being gone over weekly for this purpose.

The number of adult insects to be found in the barracks was greatest during these two months.

During November the number of adults and larvæ gradually diminished, and by the end of the month no adults could be found, and no fresh batches of larvæ appeared in any of the breeding places.

IV. *The Stables Section.*

This section is an extension of the previous one, and as it contains a similar class of breeding place, it is unnecessary to record the operations regarding it in detail. It should be mentioned, however, that during August *anopheles* larvæ were found on several occasions in two wells in this area which were not often used. The level of the water in these wells was about 30 feet from the surface.

V. *The Garden Section.*

This is chiefly a record of numerous pools formed in the gardens of the officers' houses, as the result of irrigation or of rain. From the commencement of the operations the surroundings of each bungalow were carefully examined at least once a week, and all breeding places

dealt with. Several of the officers themselves assisted in doing away with all breeding places in their compounds, and in killing all larvæ found with kerosene oil. In spite, however, of constant attention to all breeding places, adult *anopheles* could always be found in the bungalows and in the servants' quarters.

In several of the compounds as many as twenty pools containing *anopheles'* larvæ would be found at each examination, as well as small drains, iron cisterns, and the stone water reservoirs which are present in the garden of every Indian bungalow, and although all these breeding places were effectively dealt with at each examination, in less than a week they had nearly all re-formed, and become again swarming with larvæ.

One of the most difficult breeding places to deal with in this section was the waste water from the garden wells, which formed a small marshy area round the well in which *anopheles* bred freely. Wherever possible this water was drained or swept away, but in most compounds frequent application of oil was all that could be done.

Other difficult breeding places to deal with in this section were the pools of water round the roadside trees. As these pools are replenished daily by a fresh supply of irrigation water, before they have completely dried up they form favourable breeding places.

VI. *The Pools Section.*

It is unnecessary to enter into detail regarding the numerous rain-formed pools which had to be dealt with during the months of June, July, and August. The following extract from my diary will, however, give some idea of the number of pools formed by a rainfall of two hours duration on July 27.

"On the 28th July, as the result of two hours' rain yesterday, the following pools which will remain sufficiently long for the development of larvæ were found in the area :—

(1) 40 pools between 2 and 3 feet deep beyond the hospital.
(2) 12 ditches surrounding grass land beyond the hospital.
(3) 24 pools about 3 feet deep and 3 large ones about 4 or 5 feet deep beyond the Syce lines.
(4) 21 smaller pools, which will probably dry up in 3 or 4 days, between the Syce lines and the barracks.
(5) 6 very large pools and 8 smaller ones at the rifle butts. (The large pools are about 12 yards long by 10 yards wide and about 4 feet deep.)
(6) 5 large pools, 3 smaller ones, and two ditches near the Persian wheel of the fourth watercourse.
(7) 3 large pools near the last part of the fifth watercourse.
(8) 5 large shallow pools in the Royal Artillery bazaar, 10 of the

same kind near the Right Battery stables, and 3 near the Left Battery stables.

(9) A group of large pools near the Police guard.

(10) 22 deep roadside pools behind the Royal Artillery bazaar."

In addition to these, most of the surface drains were full of standing water, and innumerable small pools and broad collections of water covered the area on every hand.

Rain fell again on the 1st, and again on the 3rd of August, so that even the smaller pools had no opportunity of drying up for a week or more.

Large number of *anopheles*' larvæ were found in all these pools, and even in the broad shallow collections of water on the open plain as early as two days after their formation. As soon as larvæ were found in a pool, it was covered with a layer of kerosene oil, or dried out and marked to be filled in with earth.

By the end of October over 250 of the larger-sized pools had been filled in with broken bricks and earth.

The above is a brief account of the operations against mosquitoes carried out during the summer of 1902. The greater part of the work of filling in pools and emptying out water from the surface drains was done by contract labour, so as to avoid the necessity of constantly watching the coolies to see that they were working properly, thus leaving myself and my hospital assistant more time for searching for new breeding places. Work of this kind is also done much more quickly and less expensively by putting it out on contract than by employing a large number of coolies on a stated daily wage. My object was as far as possible to deal permanently with each breeding place as it was found, so as to avoid having to repeatedly deal with the same breeding place. This, however, can only be done with a limited number of permanent pools, and the chief difficulty met with in Mian Mir arises from the fact that the bulk of the breeding places require constant and regular attention throughout the summer.

Operations during the Winter (1902—1903).

I have already mentioned that the number of larvæ to be found in all the breeding places, and the number of adult insects present in the houses, gradually decreased during November, until by the end of the month I was not able to find any adult insects in the houses, and no new batches of *anopheles*' eggs or larvæ appeared in any of the breeding places. It was necessary to find out whether the disappearance of adult *anopheles* was complete, or whether a certain number still

remained in the houses in a "hybernating" condition throughout the winter, ready to lay their eggs when the warm weather came again in the spring. During December and January I made experiments to test this point. In the first place, I allowed all favourable breeding places to remain untouched during December. If any adult female *anopheles* were really present in the houses, it was almost certain that some of them at least would occasionally come to the pools and lay their eggs, as they had always done during the summer, for though the nights during December were very cold, the days were still warm and sunny. That *anopheles* if they are present in a place will lay their eggs during December in the Punjab is proved by the fact that a few adult *anopheles* caught at Ferozepore at the end of December readily laid eggs on January 1. During December, however, not a single *anopheles'* egg or young larva was found in any of the breeding places in the area of operations at Mian Mir. This is strong evidence, therefore, that all adult *anopheles* had disappeared from the area.

Further proof was afforded by the following experiment:—

Having chosen a house in which abundant adult *anopheles* has been constantly found during the summer, I covered the floor with a sheet, and having carefully closed all outlets, four or five cones composed of a mixture of nitrate of potash, charcoal, sulphur, and pyrethrum powder were burnt in the house for three hours. During the summer I had proved that two of these cones burnt in a house of the same size were sufficient to kill all the *anopheles* it it. In December, however, not a single dead *anopheles* was found on the sheet spread on the ground, This experiment was repeated in a number of houses, stables, sheds, arches of bridges, and other places in which it appeared probable adult *anopheles* might hybernate through the winter.

Numerous *culex* (which were very plentiful in December and January, and laid their eggs regularly in the breeding places) were killed by this method, but no *anopheles*. I conclude, therefore, that all *anopheles* had disappeared from the area by the beginning of December.

This disappearance cannot, however, be attributed to the operations, for a similar disappearance was noted in other parts of the cantonment where no operations had been carried on, and the same almost sudden disappearance had been noted by us at the end of November, 1901.

It should be mentioned that in parts of the cantonment where no operations had been carried on, and in Lahore (4 miles from Mian Mir) *anopheles'* larvæ could still be found in permanent breeding places throughout the months of December and January. These larvæ, however, are not newly hatched ones; they are old larvæ which were hatched in October and the first part of November, but which on account of the cold are not able to develop into pupæ and adults until the spring. They remain alive in a sluggish condition throughout the winter, and form without doubt one means by which *anopheles* can tide

over the cold of winter and re-appear in the spring. My object during the winter has been to kill off all these "hybernating" larvæ throughout as wide an area as possible round the Royal Artillery lines. Up to the middle of January this had been done within a radius of a mile in every direction from the lines. If *anopheles* appear in any number in the area in the spring, it must mean that they have come in from a distance of at least a mile, for we may say with some certainty that no adults or larvæ exist at the present time within this distance of the area.

II. *Other Operations.*

I have already mentioned that the native children in the different followers' lines and in the Royal Artillery bazaar form the chief source from which *anopheles* mosquitoes become infected. It was desirable, therefore, as far as possible to minimise the effect of these large sources of mosquito infection. The measures by which this could be done were—(1) The removal of the infected children from the vicinity of the barracks, or—(2) The treatment of all infected children with quinine.

The nearest and most heavily infected body of children were those in the Syce lines of the Right Battery. These Syce lines contained about 78 children, and in October, 1901, over 56 per cent. of them had malaria parasites in their blood. The distance of these lines from the barracks of the men is less than 180 yards. Arrangements were made to have the inhabitants of these lines removed into tents on a site half a mile away from the nearest barrack, and this measure was carried out in August. By this means the most dangerous source of infection of *anopheles* was undoubtedly done away with.

The second dangerous source of infection of *anopheles* was afforded by the children in the hospital followers' quarters, which are situated at the back of the hospital compound about 40 yards from the hospital and prison, and about 400 yards from the main barracks of the troops.

It was found impracticable to have the hospital followers and their families moved into new quarters at a distance from the hospital, and I decided, therefore, to treat all the children regularly with quinine. They numbered 34 in all. The treatment was commenced on August 30, and each child received a dose of from 5 to 10 grains of quinine, according to age, once a day for the first ten consecutive days, and afterwards a dose of 10 grains of quinine twice a week throughout September, October, and November. In the middle of October when in spite of the treatment a few new infections occurred among the children, ten days consecutive treatment was again given to those children in whose blood parasites were found, and again at the end of November, when the season of new infections had passed, all the children were again given ten days' consecutive treatment in order

to completely kill off any parasites which might still have resisted the previous treatment.

It was found that even children of one or two years of age could stand a daily dose of 10 grains of quinine without any ill effect. After the first three or four days most of the children took the quinine readily and apparently got to like the bitter taste.

The third and fourth sources of infection of *anopheles*, in order of importance, were the Royal Artillery bazaar and the second series of Syce lines.

Mosquito destruction was the only prophylactic measure carried out in the Royal Artillery bazaar, as it was necessary to keep one body of children untreated with quinine in order to test the efficacy of the operations against mosquitoes.

The children of the second series of Syce lines, which are situated at a distance of 400 yards from the nearest barrack, were infected with malaria parasites to the extent of 20 per cent. in October, 1901. From September 10 to the end of November, 1902, they were regularly treated with quinine in the same manner as was being done with the hospital followers' children. They numbered 103 in all, and each child received a daily dose of from 5 to 10 grains of quinine for the first ten days, and afterwards a dose of 10 grains twice a week on consecutive days.

Prophylaxis by the Administration of Quinine to the Troops.

In addition to the measures described above, all the British soldiers in the cantonment received a dose of 10 grains of quinine twice a week on consecutive days. The chief object of this measure was to prevent relapses of old infections. We have found that at the end of November, 1901, 22·2 per cent. of the men of the Royal Artillery who were doing their duty and who were apparently quite healthy, had malaria parasites in their blood, so that it was evident some measure by which relapses of these infections might be prevented was necessary. The administration of quinine was commenced on April 18, and continued throughout the summer.

Part III.—Results.

In considering the results of the operations up to the present time, we may take first the results obtained with regard to the prevalence of *anopheles* mosquitoes.

On this important point the following conclusions must, I think, be admitted :—

(1) The operations were commenced at a favourable time when very few, if any, adult *anopheles* were present in the houses, and very few, if any, larvæ in the breeding places.

(2) In spite of the operations, the number of larvæ found in the breeding places, and the number of adults present in the houses gradually increased month by month to a maximum in September and October, and then quickly decreased during November and the beginning of December, in spite of the operations being discontinued during the latter month.

(3) As a result of the operations, the increase in the number of *anopheles* which occurred each month was to a great extent checked, so that the actual number of *anopheles* present in the houses at any time during the year was not nearly so great as it would have been had no operations been carried on.

(4) In spite of the check on the breeding of *anopheles*, the actual number present in the houses from July to November was such that specimens of both species, *A. culicifacies* and *A. Rossii*, could be caught fairly easily at any time.

(5) Within the area of operations the number of adult specimens of *A. culicifacies* present in the houses was less than in other parts of the cantonment where no operations had been carried on.

(6) The number of adult specimens of *A. culicifacies* present in the houses of the area during the year of operations was less than during the preceding year. This cannot be said with certainty regarding parts of the cantonment (*e.g.*, the British Infantry bazaar) where no operations were carried on. If in these other parts any difference between the number of *A. culicifacies* present in the houses in 1901 and 1902 existed, it was so slight as not to be detectable by searching. In the Royal Artillery bazaar, however, it was quite evident to one who had regularly searched the houses during both years, that a measurable reduction in the number of *A. culicifacies* had been effected.

(7) The number of larvæ of *A. culicifacies* to be found in the cleaned canals and watercourses was certainly less than in the uncleaned ones, and for this reason less than could be found during the preceding year.

(8) Regarding *A. Rossii* it cannot be said with certainty that the number of adult specimens present in the houses within the area of operations was less than in other parts of the cantonment, nor, in my opinion, was the number of this species to any marked extent less than in the preceding year. In 1902, as in 1901, this species was so abundant in all parts of the cantonment that any difference which existed was negligible. Except on the supposition that they came from some place outside the area of operations, which extended to a distance of nearly half a mile in every direction from the houses

where the adult insects were caught, it is difficult to account for the almost sudden appearance of large numbers of this species which occurred at the beginning of July. It is also difficult to account for the fact that in spite of all breeding places of this species within the area being regularly dealt with, the number of adult insects present in the houses increased very greatly instead of diminishing.

It is evident, therefore, that the problem of materially reducing the number of *anopheles* in Mian Mir is a difficult one. As a result of the operations a reduction in the number of the malaria-carrying species (*A. culicifacies*) has been effected, but the reduction is not sufficient to prevent specimens of this species from still being found fairly easily in the houses, which means that they are present in fair abundance.

The chief difficulty lies in the fact that the majority of the breeding places in Mian Mir are such that they cannot be permanently done away with, and it seems doubtful whether any operations short of permanent elimination of all possible breeding places will produce a marked reduction in the number of *anopheles*. It should be remembered, however, that the operations have only been in progress about nine months, and that by continually rendering all possible breeding places inhospitable for larvæ, a permanent diminution may in time be effected. It is impossible also to predict what effect will be produced by the winter operations, during which I hope to be able to kill off all larvæ within a wide distance of the area of operations, and assuming that my observation regarding the complete disappearance of all adult *anopheles* from the area is correct, it will be interesting to note by what means adult insects re-appear in the area in the spring.

Secondly, we may consider whether any reduction in the amount of malaria has been effected, and if so the means by which this has been brought about.

In order of importance the tests of a reduction in the amount of malaria are:—

(1) A reduction in the amount of malaria in the regimental bazaars as measured by the percentage of young children found infected with malaria parasites.

(2) A reduction in the percentage of infection with malaria parasites among the troops.

(3) A reduction in the number of admissions for "ague" among the troops.

I.—The Amount of Malaria in the Regimental Bazaars.

1. *The Royal Artillery Bazaar.*

In this bazaar mosquito destruction was the only prophylactic measure carried out.

The percentage of infection of the children, and their spleen rates at the height of the fever season in 1901 and 1902, are shown in the following table:—

Royal Artillery Bazaar.

	October, 1901.	October, 1902.
Percentage of infected children	35	20
,, with enlarged spleens	75	64

In the year of operations, therefore, there was a reduction in the amount of malaria in this bazaar.

It should be noted, however, that in the British Infantry bazaar, where no operations were carried out and which was kept for the purpose of control observations, a reduction in the amount of malaria also occurred during 1902. This is shown in the following table:—

British Infantry Bazaar.

	October, 1901.	October, 1902.
Percentage of infected children	52	42·3
,, with enlarged spleens	80	69

It may be assumed, therefore, that a reduction in the percentage of infected children of the Royal Artillery bazaar would also have occurred in 1902 in the ordinary course of events and in the absence of any operations.

A closer examination of the figures shows, however, that over and above the decrease which would have occurred in 1902 in consequence of the year being an unusually healthy one, there was an additional decrease which may fairly be ascribed to the operations against mosquitoes. The decrease which occurred in the British Infantry bazaar in the absence of any operations is represented by the proportion as 1·23 : 1, and the decrease in the Royal Artillery bazaar, where mosquito destruction was carried on, is represented by the proportion as 1·75 : 1, a much greater decrease than can be accounted for solely by the fact of the year being an exceptionally healthy one.

The difference between the relative decrease of the spleen rates in the two bazaars is not so marked, being represented by the proportions as 1·159 : 1 in the British Infantry bazaar, and as 1·171 : 1 in the Royal Artillery bazaar respectively; but this is accounted for by the fact that in places where there are a large number of chronically-enlarged

spleen cases, even in the entire absence of new infections, it takes many months for the spleen rate to diminish very markedly.

The difference between the percentage of infected children in these two bazaars in September was much greater than in October, and it is reasonable to conclude from the following table that the onset of the season of greatest liability to infection had, as a result of the operations against mosquitoes, been delayed, and that the season had been shortened in the Royal Artillery bazaar.

Table showing the Percentage of Infected Children during some Months of the Years 1901 and 1902 in the Royal Artillery Bazaar and in the British Infantry Bazaar respectively.

		Royal Artillery Bazaar.	British Infantry Bazaar.
October,	1901	35	52·0
November	,,	—	22·0
December	,,	29	—
April	1902	21	—
June	,,	5	8·3
July	,,	4	8·5
August	,,	4	15·0
September	,,	4	32·2
October	,,	20	42·3
November	,,	12	27·0

We may fairly conclude, therefore, that purely as the result of a reduction in the number of *anopheles* (*A. culicifacies*), a reduction in the amount of malaria in this bazaar occurred. We have already seen that the reduction in the number of *anopheles* in this bazaar was not very marked, though it was quite apparent to one who had regularly searched the bazaar during both the years of observation. Had it been possible to have effected a greater diminution in the number of *A. culicifacies*, there is little doubt that the amount of malaria would have been reduced to a far greater extent. *The experiment shows that even a slight reduction in the number of anopheles affects the amount of malaria to an extent which is quite measurable.*

2. *The First Series of Syce Lines.*

The operation carried out with regard to these lines was the removal of all the inhabitants into tents on a new site.

The results of this experiment were very striking.

The old site was situated within 140 yards of an irrigation water-course, in which numerous *anopheles* (*A. culicifacies*) were breeding, and many adult insects of this species were present in the houses in

October, 1901. At that time 56·5 per cent. of the children were found infected with malaria parasites.

The new site was situated on the open plain, three-quarters of a mile from the nearest irrigation watercourse, and over 600 yards from the nearest pool, and as a result of this no adult *anopheles* were found in any of the tents during September and October of the year of operations.

Throughout the season not a single case of fever occurred among the adults in these tents, and on October 24 (at the height of the fever season) parasites were found in only 1 child out of 25 examined. Thus by their removal from the vicinity of *anopheles'* breeding places, and without treatment of any kind, the percentage of infection of these children had been reduced from 56·5 in October, 1901 to only 4 in October, 1902. Their spleen rate also had decreased from 75 per cent. in April, 1902, to 60 per cent. in October, 1902.

This experiment affords a good proof that if it is possible to do away entirely with breeding places of *anopheles* in any place, malaria quickly disappears. It should be mentioned that in every respect other than proximity to breeding places of *anopheles*, this body of people were under the same conditions in the new site as they had been in the old, except that being in tents they were more exposed to the sun and rain than they had been in their houses on the old site.

3. *The Hospital Followers' Lines.*

The measure carried out in these lines was the treatment of all the children with quinine. These children were not examined in October, 1901, but judging from the fact that in June, 1902 (the month in which malarial fever is least prevalent in Mian Mir) 60 per cent. of the children had enlarged spleens, it is reasonable to conclude that had they been examined during the fever season of 1901, a large proportion would have been found infected. In the middle of August, before quinine treatment was commenced, I found parasites in 2 out of 25 children examined. The treatment was commenced on August 30, and September 15 I was unable to find parasites in slides from any of 25 children examined, nor again in the same number examined on October 6. On October 24, however, I found parasites in 4 children out of 25, that is, at the height of the fever season 16 per cent. of the children were infected in spite of the treatment. These new infections, however, were quickly cured by daily treatment for 10 days, and I consider that this source of infection of *anopheles* was greatly minimized, if not entirely eliminated. Probably a certain number of *anopheles* became infected from these children before the treatment was commenced, and another year it would be advisable to begin it earlier in the year. The effect of the treatment on the spleen rate is shown in the following table :—

To show the Effect of Quinine Treatment on the Hospital Followers' Children. (Total number = 34.)

		Total number with enlarged spleens.
August	30	18
September	9	13
„	29	12
October	6	9
„	20	13
November	4	12
„	24	8

4. *The Second Series of Syce Lines.*

Quinine treatment was also earried out on the children in these lines.

At the height of the fever season in October, 1901, 20 per eent. of these children had been found to be infected with malaria parasites. As a result of the quinine treatment I was unable to find parasites in any of 25 children examined in October, 1902. The effect on the spleen rate is shown in the following table:—

To show the Effect of Quinine Treatment on the Children of the Syce Lines. (Total number = 103.)

	Percentage of Enlarged Spleens.
October, 1901	20·0
September 1, 1902	15·5
„ 29, 1902	2·9
October 10	4·9
November 15	3·9
„ 25	1·9

III.—The Number of Admissions for Malarial Fevers among the Troops.*

It is generally agreed that the year 1902 was an exceptionally healthy one for all troops in the Punjab, and for this reason it was an unfavourable year for testing the efficacy of prophylactic measures by means of hospital statistics.

The number of admissions for ague among British troops throughout

* I regret that, from want of time, I have been unable to carry out the second test, viz., the examination of films of blood from a large number of men in the British Infantry and Royal Artillery, in order to ascertain whether a reduction in the percentage of infection of the troops themselves has taken place.

f 3

the cantonment of Mian Mir was, I understand, the lowest ever recorded in this station.

The following tables have been furnished me by the senior medical officer, Mian Mir.

Table I.—Statement of the Admissions and Deaths from Malarial Fevers among the British Troops at Mian Mir for the Five Years 1898 to 1902.

Years.	Strength.	Admissions.	Deaths.	Ratio per 1000.	
				Admission .	Deaths.
1898	869	702	1	808	1
1899	853	400	1	469	1
1900	814	871	2	1079	2
1901	808	1094	1	1354	1
1902	731	197	1	269	1

As shown on p. 31, the average annual admission rate per 1000 for malarial fevers in Mian Mir is 663, and the rate of only 269 for 1902 compares very favourably with this.

Table II.—Statement showing separately the Admissions and Deaths from Malarial Fevers among the British Infantry and the Royal Artillery in Mian Mir for the Years 1900—1902.

Years.	Corps.	Strength.	Admissions.	Deaths.	Ratio per 1000.	
					Admissions.	Deaths.
1900	Royal Artillery	259	132	1	509	4
	British Infantry	555	746	1	1344	2
1901	Royal Artillery	225	346	1	1538	4
	British Infantry	583	748	0	1283	0
1902	Royal Artillery	172	66	0	384	0
	British Infantry	559	131	1	234	2

e III.—Statement showing the Number of Admissions for Malarial Fevers into the British Infantry and Royal Artillery Hospitals monthly during 1902.

British Infantry Hospital.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly strength	690	651	667	507	335	321	308	306	314	893	955	601
Admissions	15	19	13	5	10	4	3	0	0	31	25	7

Royal Artillery Hospital.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly strength	*	*	98	311	298	287	276	267	272	263	*	*
Admissions	..	..	4	5	4	8	1	1	2	12		

Table IV.—A Comparison of the Admissions for Malarial Fevers during 1901 and 1902.

Hospital.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
British Infantry	1901	144	61	67	35	61	53	15	32	46	58	116	65
	1902	15	19	13	5	10	4	3	0	0	31	25	7
Royal Artillery	1901	20	2	3	6	38	33	22	42	44	75	40	16
	1902	*	*	4	5	4	8	1	1	2	12	*	*

* The regiment was absent from the station.

It is evident from these tables that, during the year 1902, the prevalence of malarial fevers among the troops in Mian Mir, as shown by statistics, has been remarkably less than in previous years. It is difficult to determine accurately the factor to which most credit should be given for this great decrease in the admission rate—a decrease which was equally notable in the British Infantry lines where no operations against mosquitoes were carried on, and in the Royal Artillery lines, which were within the area of these operations. In the first place, the year 1902 was, as a whole, far more healthy than 1901. Regarding this, we have the figures for the British Infantry bazaar as an indication of the difference between the two years. At the height of the fever season in 1901, the endemic index of this bazaar was 52 and the spleen rate 80 per cent. At the same time in 1902 the endemic index was 42·3, and the spleen rate 69 per cent. There was certainly, therefore, a marked difference between the two years, but not, in my opinion, a difference sufficient to account entirely for the large decrease which occurred in the admission rate of the British Infantry. A large proportion of the immunity enjoyed by these regiments, therefore, must be attributed to the prophylactic issue of quinine (which was carried out during 1902 under strict supervision), for no other prophylactic measures than this were undertaken in the British Infantry lines. In former years it has been usual to issue the quinine in bulk from the hospital to a non-commissioned officer of the regiment, and no control was exercised to see whether the men took the quinine or not. It is probable that not one man in ten ever took the quinine, for very few European soldiers will take this drug if they can possibly avoid doing so. During 1902, however, all the troops were marched to the hospital twice a week, and the quinine was given under the supervision of a medical officer, so that the majority of the troops, at any rate, took the prophylactic dose regularly.

To this fact, therefore, I attribute in large measure the low admission rate for malarial fevers among the British Infantry.

A certain margin must also be allowed for errors in diagnosis. I am informed that during 1901 it was the rule to admit every case of fever at once and return it as "ague." During 1902 much greater care was taken in diagnosis, and it is even possible that, in the British Infantry hospital, a few cases, which were really due to malarial fever, were returned under some other heading; for it is difficult to believe that, during August and September, not a single case of malarial fever should have occurred among over 300 men at a time when the endemic index of the regimental bazaar was increasing rapidly (15 per cent. in August and 32 per cent. in September), and when, from the reports of British officers living in the lines, a large number of native servants were suffering from malarial fever.

The events which happened in 1902 render it very difficult to form a correct estimate from the hospital statistics of the efficacy of the operations carried out in the Royal Artillery lines. These events were the arrival of a second regiment into the British Infantry lines at the beginning of October, and the departure of both batteries of Royal Artillery to Delhi at the end of that month. From the beginning of October, also, the Royal Artillery hospital was made a sick depôt, to which men who fell ill on the line of march to Delhi at other places than Mian Mir were returned. The twelve admissions recorded into this hospital in October (Table III) consisted chiefly of such cases as these, as well as of chronic malarial cases transferred from hill stations. For the same reasons the statistics of the Royal Artillery hospital show 9 admissions for malarial fever out of a strength of 54 during November, and 16 admissions out of a strength of 47 during December.

The inclusion of these figures in the annual return of Table II has made it appear that the ratio of admissions per 1000 among the Royal Artillery was greater during 1902 than that among the British Infantry. (Table II. Ratio of admissions of the Royal Artillery = 384 per 1000; of the British Infantry = 234 per 1000.)

Where so many factors affect the statistics it is, in fact, impossible to obtain any results of value from their consideration. It is, however, a matter for congratulation that, although during 1900 and during 1901 the death rate for malarial fevers among men of the Royal Artillery was much higher than among the British Infantry, during 1902 the results are reversed in favour of the Royal Artillery (*vide* Table II).

A few words may be added regarding the respective value of the different methods of prophylaxis attempted in Mian Mir.

That mosquito destruction, if it can be carried out successfully, will effectually banish malaria, is, I think, sufficiently proved by the results obtained in the Royal Artillery bazaar and in the first series of Syce lines (pp. 68—70). Even though it was not possible to reduce the number of *anopheles* very markedly in the Royal Artillery lines, a decrease in the amount of malaria in the Royal Artillery bazaar greater than can be accounted for, by reason of the year being an unusually healthy one, was effected. This decrease can only be attributed to the operations against mosquitoes.

In the Syce lines, which by their removal were taken entirely out of the range of *anopheles*, malaria almost entirely disappeared.

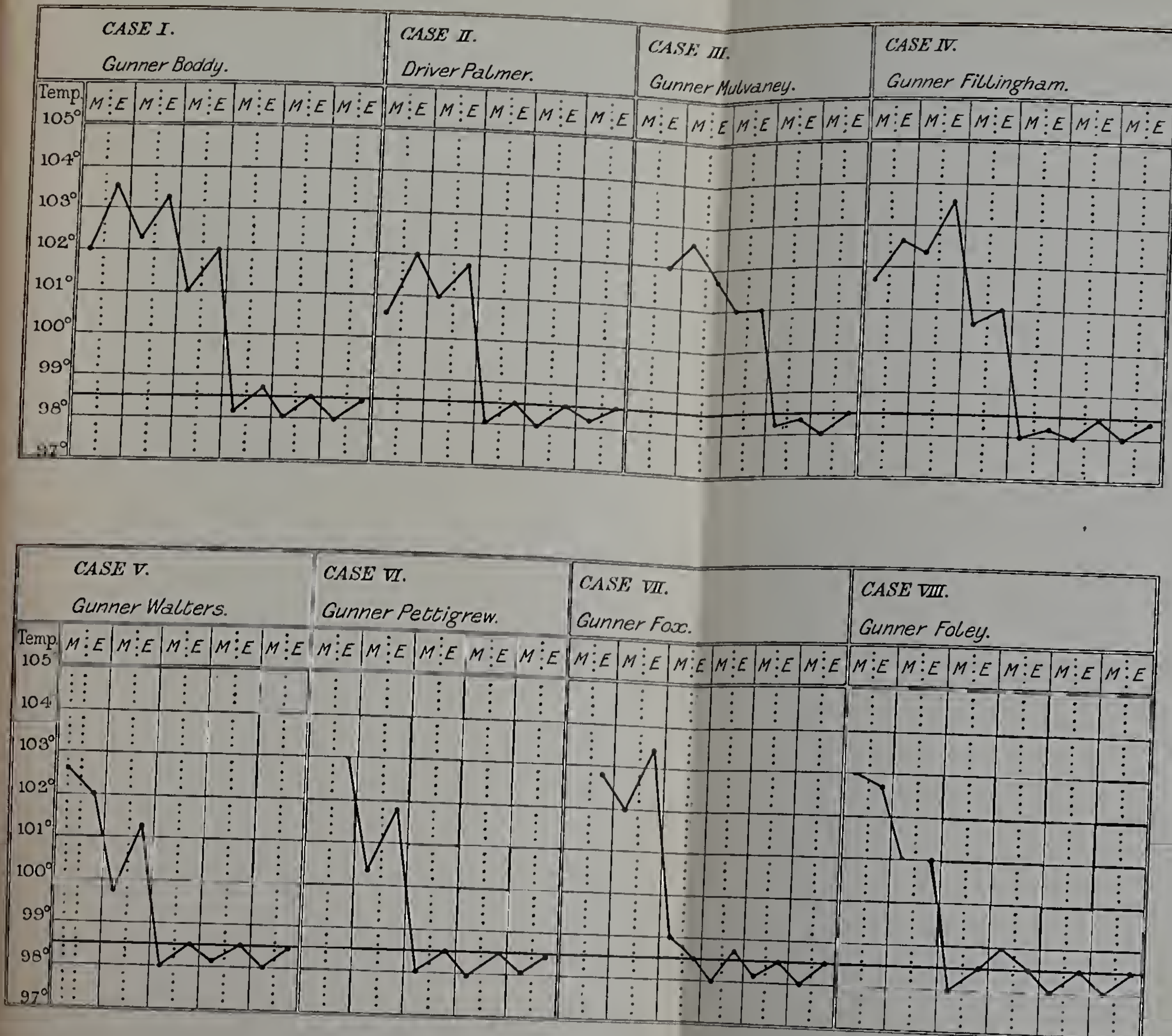
From a practical point of view the chief drawback to mosquito destruction is its difficulty and expense. It must be admitted that although we have been given, practically speaking, a free hand in

matters of expenditure and in the amount of labour employed, and although my own services and those of a hospital assistant have been confined exclusively to this work, we have, during the summer, made but little impression on the number of *anopheles*. It remains to be seen what the results of the winter operations, and those of the coming summer, will be; but unless a more marked reduction in the number of *anopheles* can be effected this year than during the previous one, it would, I think, be inadvisable to continue operations on these lines in Mian Mir during a third year.

During the present year, however, it is extremely important for the operations against mosquitoes to be carried on with great vigour, because although it might not be possible to produce much effect during the first year of operations, yet continuous efforts carried out over a period of two years may produce a very different result.

I attribute great value to the other operations carried out, viz., the attempt to lessen the effects of obvious sources of infection of *anopheles* in cantonments, either by the removal of infected children from the vicinity of barracks or by their treatment with quinine.

The latter is a measure which requires no special knowledge, and one which is applicable to every place where large numbers of native children are gathered together in the vicinity of European troops. One of the features of the year was the marked freedom from attacks of malaria of the adult Syces in the Royal Artillery lines. No statistics are available regarding these men, but the faet was apparent to all the officers of the Royal Artillery, and the contrast between the health of adult native servants in these lines and in the British Infantry lines was very marked. During 1901 all the adult Syces received a prophylactic dose of 10 grains of quinine twice a week, but I am informed that, in spite of this, great difficulty was frequently experienced in getting the work done on account of the large number of Syces constantly away with fever. During 1902, however, *although none of the adult Syces received prophylactic doses of quinine*, scarcely a single case of fever occurred among them throughout the year. I attribute this almost entirely to the treatment of the children (who are undoubtedly the chief source of infection of *anopheles*) with quinine, and in the case of the first series of Syce lines to their removal from the range of *anopheles*.



Temperature charts of fever cases usually returned in military hospitals as "ague," but in which repeated examinations failed to show the presence of malaria parasites, and which recovered without any quinine treatment (p. 32).

Appendix B.

A Rough Statement of the Expenses incurred for the Anti-Malarial Operations at Mian Mir (to October 31, 1902).

No.	Item.	Cost. R	a.	p.
1	Wages of coolies at 4 annas each per day	711	0	0
2	Filling pools. Work done by contractors (202,601 cubic feet)	596	4	2
3	Emptying pools and drains. Work done by contractors	194	12	0
4	Brick-lining and plastering watercourse. Total length, 4985 feet	5364	14	6
5	Contingent expenses for kerosine oil, materials, etc., about	350	0	0
	Rupees	7216	14	8